ENVIRONMENTAL • GEOTECHNICAL
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GEOTECHNICAL ENGINEERING INVESTIGATION

PROPOSED INTERSECTION IMPROVEMENT PROJECTS
17TH STREET AT NORTH DUNN STREET
17TH STREET AT KINSER PIKE/MADISON STREET
BLOOMINGTON, INDIANA

ATC PROJECT NO. 170GC00756

MAY 3, 2019

PREPARED FOR:

LOCHMUELLER GROUP, INC.
6200 VOGEL ROAD
EVANSVILLE, INDIANA 47715

ATTENTION: MR. NICHOLAS WILL, P.E.

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May 3, 2019

Mr. Nicholas Will, P.E.
Lochmueller Group, Inc.
6200 Vogel Road
Evansville, Indiana 47715

Re: **Geotechnical Engineering Investigation**
Proposed Intersection Improvement Projects
17th Street at North Dunn Street
17th Street at Kinser Pike/Madison Street
Bloomington, Indiana
ATC Project No. 170GC00756

Dear Mr. Will:

Submitted herewith is the report of our geotechnical engineering investigation for the referenced project.

This report contains the results of our field and laboratory testing program, an engineering interpretation of this data with respect to the available project characteristics and recommendations to aid design and construction of the earth-related elements of this project. We wish to remind you that we will store the samples for 90 days after which time they will be discarded unless you request otherwise.

We appreciate the opportunity to be of service to you on this project. If we can be of any further assistance, or if you have any questions regarding this report, please do not hesitate to contact either of the undersigned.

Sincerely,

John Evans

John Evans, EIT
Staff Engineer

ELLEN ANNE W. WILKINSON
No. 10707526

Ellen Anne W. Wilkinson, P.E.
Senior Geotechnical Engineer

SUMMARY OF GEOTECHNICAL ENGINEERING INVESTIGATION

Proposed Intersection Improvement Projects

17th Street at Dunn Street & 17th Street at Kinser Pike/Madison Street
Bloomington, Indiana
ATC Project No. 170GC00756

The following information is an abbreviated summary that is presented in further detail within the attached report. This summary is solely for the purpose of providing a brief project overview. The complete report should be read in its entirety prior to the implementation of any information in the design and construction of this project. This brief project summary omits a number of details that are presented in the full report, any one of which could be crucial to the proper implementation of the design recommendations, and thus this summary shall not be considered complete and shall not be used for the purposes of design.

GENERAL INFORMATION

The project sites are located on 17th Street at the intersections of 17th Street with Dunn Street and 17th Street with Kinser Pike/Madison Street on the north side of Bloomington, Indiana. It is our understanding that the earth related elements of the project at 17th Street and Dunn Street will consist of the installation of a new traffic signal, potential roadway realignment and/or reconstruction, retaining walls, and drainage improvements including storm water drains. The project at 17th Street and Kinser Pike/Madison Street will consist of the installation of a new traffic signal in addition to mill and overlay of the existing pavement. Both projects will include sidewalk work.

ROADWAY RECOMMENDATIONS

The pavement subgrades at both intersections are anticipated to consist primarily of naturally-occurring, high plasticity cohesive soils; or engineered fill similar to the near-surface soils observed at the test boring locations. The subgrade treatment should be in accordance with INDOT Standard Specifications Section (ISS) 207.04.

Given the urban environment and potential for shallow utilities in areas of pavement rehabilitation and deep patching a Type IV subgrade treatment is recommended for use at the intersections of 17th Street with Kinser Pike and 17th Street with North Dunn Street. Subgrade treatment Type IV shall be in accordance with ISS 207.04 consisting of 12 inches of the subgrade excavated and replaced with coarse aggregate No. 53 on Type IB Geogrid. No additional foundation improvement is required.

A resilient modulus value of 5,400 lbs/sq.in. is recommended for use in pavement design for the natural subgrade soil. A resilient modulus value of 8,000 lbs/sq.in. is recommended for use in pavement design in conjunction with Type IV subgrade treatment for 17th Street maintenance of traffic and shoulder widening. The table on the following page summarizes the recommended pavement design parameters for the predominant subgrade soils.

Pavement Design Parameters

	Kinser Pike	North Dunn Street
Natural Subgrade Soil Resilient Modulus Value, lbs/sq.in.	5,400	5,400
Modified/Prepared Subgrade Soil Resilient Modulus Value, lbs/sq.in.	8,000	8,000
Predominant/Critical Subgrade Soil	SILTY CLAY LOAM A-7-6	SILTY CLAY LOAM A-7-6
Percent Passing #200	98	98
Percent Silt	70	70
Liquid Limit, percent	47	44
Plastic Limit, percent	16	19
Plasticity Index, percent	31	25
Approximate Depth to Ground Water, ft	3.5	4.0
Natural Dry Density of Natural Subgrade (pcf)	120	120
Range of Natural Moisture of Natural Subgrade, percent	26 to 30	18 to 27
Maximum Organic Content, percent	<5	<5
Maximum Marl Content, percent	<3	<3
Maximum Sulfate Content, ppm	Not Tested	Not Tested
Filter Fabric Required for Underdrains	Yes : 918.02 (b) Type 1A	
Subgrade Treatment	Type IV	

Report Prepared By:
John Evans, EIT
Staff Engineer

Report Reviewed By:
Ellen Anne W. Wilkinson, P.E.
Senior Geotechnical Engineer

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1 INTRODUCTION

This report presents the results of our geotechnical engineering investigation for the 17th Street intersection improvements at the intersections of 17th Street with North Dunn Street and 17th Street with Kinser Pike/Madison Street on the north side of Bloomington, Indiana.

The geotechnical engineering investigation was performed to characterize and evaluate the soil and ground water conditions beneath the project site and to develop recommendations for use in the design of the replacement structure foundations. The investigation consisted of an exploratory test drilling and sampling program, laboratory testing of soil samples obtained from the test borings, engineering analyses and preparation of this report.

2 PROJECT DESCRIPTION

Lochmueller Group, Inc. is developing plans for the 17th Street intersection improvements at the intersections of 17th Street with Dunn Street and 17th Street with Kinser Pike/Madison Street on the north side of Bloomington, Indiana.

It is our understanding that the earth related elements of the project at the intersection of 17th Street with North Dunn Street will include pavement reconstruction, HMA widening and overlay, curb and gutter, sidewalks, curb ramps, retaining walls, storm sewer, and traffic signal. Relatively short retaining walls will be constructed at the northwest and south west corners of the intersection. The project will add a left turn lane along the west approach and construct a 10 ft. wide path along the north side of 17th Street.

The project at the intersection of 17th Street with Kinser Pike/Madison Street will consist of the installation of a new traffic signal and a 10 ft. wide path along the north side of 17th Street in addition to milling and overlay of the existing pavement. The 17th Street and Kinser Pike/Madison Street project is not expected to include any retaining walls, culverts or storm drains. Both projects will include sidewalk work.

3 PURPOSE AND SCOPE OF WORK

The purpose of this study was to determine the general subsurface conditions at the proposed roadway project by drilling three soil test borings and to evaluate the subsurface conditions with respect to construction of the earth related elements of the proposed project.

3.1 Field Investigation

The subsurface conditions for the proposed project were investigated by ATC and drilling was performed with truck-mounted drilling equipment using hollow-stem-auger methods to advance the boreholes. Split-barrel samples were obtained using standard penetration test (SPT) procedures (American Association of State Highway and Transportation Officials-AASHTO-Method T206) at 2.5 ft to 5.0 ft intervals. Samples of the bedrock materials were obtained using rock coring procedures in general accordance with AASHTO T225. The equipment used to obtain the cores was a conventional

"NQ2" double tube core barrel system with a diamond cutting bit. Rock cores were completed in 5-foot runs. Recovered cores were measured in order to determine the recovery and the rock quality designation (RQD) in accordance with ASTM D-6032. The rock cores were field classified and placed in rock core boxes for transport to our geotechnical laboratory for further analysis.

The test boring locations were staked in the field by ATC representatives based upon the design plans provided by the designer. Approximate boring elevations were estimated from Google Earth and station and offset estimated from existing plans. The test borings were drilled at the approximate locations noted on the test boring logs in Appendix B and as depicted on the Boring Plans (Figures 3 and 4 in Appendix A).

Logs of all borings, which show visual descriptions of all soil strata encountered using the AASHTO classification system are included in Appendix B. Sampling information and other pertinent field data and observations are also included on the boring logs. In addition, a sheet defining the terms and symbols used on the logs and explaining the SPT procedure is provided immediately preceding the test boring logs in Appendix B.

3.2 Laboratory Investigation

The disturbed soil samples were visually classified by an engineer in accordance with the AASHTO Soil Classification System and the visual classifications were verified or modified based upon the results of laboratory tests. Final boring logs were subsequently prepared and are included in Appendix B.

Soil index property tests including natural moisture content tests (AASHTO T265), grain size analyses (AASHTO T88), Atterberg limits tests (AASHTO T89 and T90), were performed on representative soil samples. In addition to the soil index property tests, calibrated hand penetrometer tests ("pocket penetrometer" tests) were performed on selected samples. The results of laboratory tests are included on the boring logs in Appendix B and/or on the test report sheets in Appendix C.

4 GENERAL SITE CONDITIONS

4.1 Regional and Site Geology

The project site is located in the Mitchell Plateau Physiographic Division, which is part of the Southern Hills and Lowlands Region of the State of Indiana and overburden soils mainly consist of loess over clayey residual soils. Based upon information provided by the Indiana Geological Survey (IGS) the depth to bedrock in this area typically ranges from 0 to 50 ft to bedrock beneath natural grade (El. 800 ft. to 850 ft.). The project sites lie within the Sanders Group, Mississippian System. The Sanders Group is described in the Rock Unit Compendium published by IGS as a skeletal limestone.

4.2 Existing Pavement and Subsurface Conditions

The general subsurface conditions at the site were investigated by drilling eight test borings to depths ranging from 9.3 ft to 18.7 ft. The subsurface conditions disclosed by the field investigation are summarized in the following paragraphs. Detailed descriptions of the subsurface conditions encountered in each test boring are presented on the test boring logs in Appendix B. It should be noted that the stratification lines shown on the test boring logs represent approximate transitions between material types. In-situ stratum changes could occur gradually or at slightly different depths.

At the 17th Street intersection with North Dunn Street, test boring RB-1 was drilled in the existing driving lane. This test boring generally encountered a pavement section consisting of about 12.0 inches of asphalt pavement, aggregate base was not encountered beneath the pavement section. It should be noted that pavement cores were not obtained for this project.

The subsurface profile encountered at the test boring locations at the North Dunn Street intersection was typically medium stiff to stiff silty clay loam (A-7-6) extending to elevations ranging from approximately El. 810.5 ft. to El. 794 corresponding to auger refusal elevations. One exception to this profile was encountered at test boring RB-1 where soft clay (A-7-5) was encountered between El. 808 and El. 810.5.

The subsurface profile encountered at the test boring locations at the Kinser Pike/Madison intersection was typically medium stiff to stiff silty clay loam (A-7-6) extending to elevations ranging from El. 790 to El. 789, corresponding to auger refusal elevations.

The cohesive soils encountered in the test borings exhibited liquid limit (LL) values ranging from 44 to 141 percent and plasticity index (PI) values ranging from 22 to 113 percent. The natural moisture content values of the soils typically ranged from about 18 to 68 percent.

A correlation between soil properties and estimates resilient modulus value is summarized below.

$$CBR = \frac{75}{1 + 0.728 * (wPI)} \qquad \mathrm{M}_R = 2555 * (CBR)^{0.64}$$

Where,

CBR = California Bearing Ratio,

w = % passing #200 Sieve (P_{200}),

PI = Plasticity Index

Table 1 presents a summary table of the laboratory test results and estimated resilient modulus by the above formulas. These values may not be used for design as the correlation may not match actual resilient modulus testing, but are considered for use as a general indication of relative performance based only on the cohesive soil types encountered along the project length.

Table 1 – Summary of Correlated Resilient Modulus Values

Sample ID	Soil Classification	Depth, (ft.)	P_{200} (%)	PI	Estimated CBR Value	Estimated Resilient Modulus (M_R) (psi)
B-101	Silty Clay Loam A-7-6	1.0 – 2.5	98.3	31	3.2	5,400

Rock coring activities commenced upon auger refusal at six of the eight test boring locations extending to the termination depth of the test borings corresponding to an elevations ranging from approximately El. 802 ft. to El. 788 ft. The recovered rock cores consist of moderately to slightly weathered limestone, consistent with the information presented by IGS. In general, the rock yielded RQDs ranging from 45% to 100% correlating to "poor" to "excellent" quality. Photos of the recovered rock cores are presented with the associated boring logs in Appendix B. Table 2 summarizes auger refusal depth and rock quality.

Table 2 – Summary of Rock Depth and Quality

Project Site	Boring ID	Approximate Auger Refusal Depth (ft.)	Approximate Auger Refusal Elevation (ft.)	Rock Core Depth (ft.)	Core Recovery (%)	Core RQD (%)	Description of Rock Quality
Kinser Pike	B-101	6.3	790	6.3 to 11.3	90	80	Good
Kinser Park	B-102	7.8	789	7.8 to 11.1 11.1 to 13.1	100 96	100 45	Excellent Poor
North Dunn Street	B-1	7.6	794	7.6 to 11.8 11.8 to13.8	76 95	60 95	Fair Excellent
North Dunn Street	B-2	9.3	800	9.3 to 14.3	100	100	Excellent
North Dunn Street	RB-1	13.5	807	Not Cored	--	--	--
North Dunn Street	RB-2	10.0	796	10.0 to 15.0	100	95	Excellent
North Dunn Street	RW-1	13.5	794	13.5 to 16.8 16.8 to 18.8	94 95	85 85	Good Good
North Dunn Street	RW-2	10.5	801.5	Not Cored	--	--	--

4.3 Ground Water Conditions

Ground water observations were made during drilling operations by noting the depth of water on the drilling tools and in the open boreholes following withdrawal of the drilling augers. Ground water was encountered in Borings B-101, B-1, B-2, RB-2 and RW-1 from a depth of about 2.7 ft to 12.8 ft below the existing ground surface while neither of the other two test borings revealed ground water. It must be noted that short term ground water level readings in cohesive soils are not necessarily a reliable indication of the ground water level and fluctuations in the level of the ground water should be expected due to variations in rainfall and other factors not evident at the time of our investigation. It is also possible that "perched" ground water may be encountered at various depths and locations at the site since water is often trapped within utility trenches, sand seams within cohesive layers, etc. and although the amount of such water is usually not significant, it is important to recognize that such ground water may be encountered at various depths and locations at the site.

5 DESIGN RECOMMENDATIONS

The following design recommendations have been developed on the basis of the previously described project characteristics (Section 2) and subsurface conditions (Section 4 and Appendix B). If there are any changes in the project criteria; including the profile grade, cross-sections, structure type, retaining wall length, etc., a review should be made by this office. The design recommendations presented herein are based on the assumption that all earth related elements of the project will be carefully and continuously observed, tested and evaluated by a geotechnical engineer or qualified geotechnical technician working under the direction of a geotechnical engineer to confirm that the earth related elements of the project are compatible and consistent with the conditions upon which the design recommendations are based.

5.1 Seismic Considerations

Based on geologic mapping and the results of the test borings, it is our opinion that the subsurface conditions at the site of the South Market Street reconstruction meet the criteria for Site Class C based on Table 3.10.3.1-1 (Site Class Definitions) in the 2017 AASHTO LRFD Bridge Design Specifications. A Design Spectral Response Acceleration Coefficient at 1-second period (S_{D1}) of 0.17 has been estimated based on Sections 3.10.3 and 3.10.4 of the 2017 AASHTO LRFD Bridge Design Specifications. Based upon S_{D1}= 0.17 the site and structure should be assigned to Seismic Zone 2 based on Table 3.10.6-1 of the 2017 AASHTO LRFD Bridge Design Specifications.

5.2 Traffic Signal Foundation Design Considerations

Tables 3a and 3b provides soil parameters for use in preliminary analysis of resistance of the traffic signal foundations based on the general soil conditions encountered in the test borings. It is important to note that the soil parameter values are estimated based upon the standard penetration test results and soil type and were not directly measured. It should also be noted that the values provided for undrained shear strength (cohesion), angle of internal friction (φ), and total unit weight are ultimate values and appropriate factors of safety of resistance factors shall be used in conjunction with these values based upon compatibility with all factors associated with the design of the traffic signal formation.

Please note also that the soil conditions encountered at the individual boring locations varied at the proposed traffic signal locations. The values in Table 3a and 3b represent the predominant conditions in these areas and should provide a reasonable estimate of the conditions to be encountered within each zone. However, it is important to understand that variations in subsurface conditions will occur. The factors of safety or resistance factors selected for design shall take into account the potential variability in the subsurface conditions.

Table 3a - Recommended Overhead Traffic Control Design Parameters – Dunn Street

Soil Parameters	Depth Below Proposed Ground Surface (ft)		
	3-6	**6-9**	**9-14**
Predominant Soil Texture	Silty Clay Loam	Silty Clay Loam	Limestone
Allowable Soil Bearing Capacity, psf	2,000	2,500	10,000
Angle of Internal Friction of Foundation Soils, φ, degrees	0	0	35
Angle of Friction between Foundation and Soil, δ, degrees	0	0	35
Cohesion of Foundation Soils, c, psf	1,000	1,250	0
Ultimate Adhesion between Soil and Concrete, psf	900	900	0
Total Unit Weight of Foundation Soil, pcf	120	120	150
Cyclic Soil Modulus, pci	200	200	800
Strain at 50% of the maximum stress, ∊50	0.01	0.01	0.001
Submerged Soil Unit Weight, pcf	57.6	57.6	87.6

Table 3b - Recommended Overhead Traffic Control Design Parameters – Kinser Pike

Soil Parameters	Depth Below Proposed Ground Surface (ft)		
	3-6	**6-8**	**8-13**
Predominant Soil Texture	Silty Clay Loam	Silty Clay Loam	Limestone
Allowable Soil Bearing Capacity, psf	1,500	2,500	10,000
Angle of Internal Friction of Foundation Soils, φ, degrees	0	0	35
Angle of Friction between Foundation and Soil, δ, degrees	0	0	35
Cohesion of Foundation Soils, c, psf	1,500	1,500	1,200
Ultimate Adhesion between Soil and Concrete, psf	900	900	0
Total Unit Weight of Foundation Soil, pcf	120	120	150
Cyclic Soil Modulus, pci	200	200	800
Strain at 50% of the maximum stress, ∊50	0.01	0.01	0.001
Submerged Soil Unit Weight, pcf	57.6	57.6	87.6

5.3 Retaining Wall Design Considerations

It is anticipated that two modular block retaining wall will be constructed as part of the proposed grading in at the west approach to the intersection of 17th Street with North Dunn Street.

Retaining Wall No. 1 will be located on the north side of 17th Street beginning at approximately Sta. 25+20, Line “B”, and ending at approximately Sta. 26+65, Line “B”. This proposed retaining wall will be located along the north side of the proposed pedestrian path. Based upon the preliminary design plans, the wall will range in height from approximately 6 ft. to 8 ft. The approximate levelling pad elevation of Retaining Wall No. 1 will range from El. 805 ft. to El. 803 ft.

Retaining Wall No. 2 will be located on the south side of 17th Street beginning at approximately Sta. 25+55, Line “B”, and ending at approximately Sta. 26+70, Line “B”. This proposed retaining wall will be located along the south side of the concrete sidewalk. Based upon the preliminary design plans, the wall will range in height from approximately 5.5 ft. to 7 ft. The approximate levelling pad elevation of Retaining Wall No. 2 will range from El. 807 ft. to El. 809 ft.

The external stability analysis of a proposed modular retaining wall is presented in Appendix E of this report. As a result, the retaining walls were found to be stable against overturning, sliding, and bearing capacity failure. An allowable bearing capacity of 2800 psf is recommended for the retaining wall with a minimum base width of approximately 8 feet. The analysis is presented in Appendix E of this report

Table 4: Recommended Parameters for Modular Block Wall Design

Parameter	Retaining Wall No. 1	Retaining Wall No. 2
Levelling Pad Elevation (ft)	803 to 805	807 to 809
Foundation Bearing Material	Silty Clay Loam A-7-6	Silty Clay Loam A-7-6
Minimum Base Width	The greater of 8 ft or 0.7H	The greater of 8 ft or 0.7H
Backfill Friction Angle, ϕ	34°	34°
Friction Angle between Foundation Soils and Foundation Material, δ	22°	22°
Foundation soil Internal Friction Angle, φ	0°	0°
Adhesion Between the Soil and Concrete, C_a (psf)	700	700
Cohesion (psf)	1000	1000
Nominal Bearing Resistance, $Q_{u,}$ (psf)	5540	5540
Bearing Resistance Factor, $\varphi_{b,}$ (psf)	0.5	0.5
Factored Bearing Resistance, $q_{b,}$ (psf)	2800	2800

5.4 Pavement Design Considerations

The pavement subgrades are anticipated to consist primarily of naturally-occurring, granular soils and medium to high plasticity cohesive soils; or engineered fill similar to the near-surface soils observed at the test boring locations. The table below summarizes the parameters and values that are recommended for the analysis and design of the pavements. The subgrade treatment should be in accordance with INDOT Standard Specifications Section (ISS) 207.04.

Although the soils encountered in the test borings appear to be suitable for support of the new/widened pavement (the existing pavement is currently supported directly upon these soils), it must be noted that even those soils that may currently be relatively firm can become unstable during construction when exposed to precipitation and construction traffic. Our experience indicates that most subgrade soils beneath existing pavements will be soft or yielding once the existing pavement section is removed, regardless of the presence of the existing pavement and apparently firm soils in the test borings.

Given the urban environment and potential for shallow utilities in areas of pavement rehabilitation and deep patching a Type IV subgrade treatment is recommended for use at the intersections of 17th Street with Kinser Pike and 17th Street with North Dunn Street. Subgrade treatment Type IV shall be in accordance with ISS 207.04 consisting of 12 inches of the subgrade excavated and replaced with coarse aggregate No. 53 on Type IB Geogrid. No additional foundation improvement is required.

A resilient modulus value of 5,400 lbs/sq.in. is recommended for use in pavement design for the natural subgrade soil. A resilient modulus value of 8,000 lbs/sq.in. is recommended for use in pavement design in conjunction with Type IV subgrade treatment for 17th Street maintenance of traffic and shoulder widening. Table 5 summarizes the recommended pavement design parameters for the predominant subgrade soils. Adequate subsurface drainage should be provided with outlets at regular intervals to minimize increase in moisture content of the pavement subgrade soils.

Table 5 - Recommended Pavement Design Parameters

	Kinser Pike	North Dunn Street
Natural Subgrade Soil Resilient Modulus Value,	5,400	5,400
Modified/Prepared Subgrade Soil Resilient Modulus Value, lbs/sq.in.	8,000	8,000
Predominant/Critical Subgrade Soil	SILTY CLAY LOAM A-7-6	SILTY CLAY LOAM A-7-6
Percent Passing #200	98	98
Percent Silt	70	70
Liquid Limit, percent	47	44
Plastic Limit, percent	16	19
Plasticity Index, percent	31	25
Approximate Depth to Ground Water, ft	3.5	4.0
Natural Dry Density of Natural Subgrade (pcf)	120	120
Range of Natural Moisture of Natural Subgrade, percent	26 to 30	18 to 27
Maximum Organic Content, percent	<5	<5
Maximum Marl Content, percent	<3	<3
Maximum Sulfate Content, ppm	Not Tested	Not Tested
Filter Fabric Required for Underdrains	Yes : 918.02 (b) Type 1A	
Subgrade Treatment	Type IV	

5.5 Storm Sewer Considerations

The results of our field borings and laboratory tests indicate that the soils encountered will typically provide sufficient support of the proposed force main, sewer line, and water lines. The borings were widely spaced across the site. Therefore, some variation must be anticipated. The recommendations provided are based upon the soils encountered at the individual boring locations. Given the urban nature of the project site, areas of fill and trapped water should be anticipated. Dewatering and shoring considerations should be based upon the soils encountered in the excavations.

Due to the wide spacing of our borings, it is recommended that the base of all excavations be inspected by a representative of the geotechnical engineer to ensure the presence of suitable bearing materials at all locations. If soft/loose unstable materials are encountered below the invert elevations of the pipe, they should be undercut as deemed appropriate by the engineer. Theses excavations should be backfilled with approved granular fill.

Stabilization and undercutting are very dependent on the site conditions at the time of construction. It is strongly suggested that a representative of the geotechnical be present during installation of the pipe to consult with the contractor to ensure that a stable subgrade and proper compaction is achieved.

In order to obtain adequate compaction of the backfill to support occasional other structures at a higher elevation and minimize settlement within the above roadway, it is recommended that a granular backfill be used versus the on-site cohesive soils.

Because of the cost of removal, it is anticipated that most of the on-site cohesive soils will be used as non-structural backfill. The shallow cohesive soils exhibited moisture contents well above their optimum. The cohesive soil used as backfill will settle over time requiring periodic fill and re-levelling.

Backfill material around the pipe and to a minimum of twelve (12) inches (or greater as manufacturer's specifications require) above the pipe should consist of manufacturer approved granular material such as sand and gravel. The backfill should be brought up in equal lifts on either side of the pipe until a minimum of twelve (12) inches of material has been achieved over the pipe. Since pavements will be constructed over segments of the new utility lines, the design subgrade elevation should also then be re-established using the approved granular backfill.

A vibratory smooth drum roller will be necessary to compact the granular material. However, it will be necessary to use hand compaction equipment to compact the granular soils adjacent to and to a height of at least three (3) feet over the pipe. Furthermore, heavy compaction equipment should not be placed on the fill material until at least three (3) feet of cover or as specified by the pipe manufacturer exists over the in-place pipe. Additionally, it is recommended that backfill above the pipes be compacted to 98% of the maximum dry density in order to minimize the potential for settlement of existing adjacent structures, including utilities and pavements, and potential future structures.

5.6 Embankments and Site Grading

It is recommended that any widened earth embankments for this project should be constructed with side slopes that are 3 (horizontal) to 1 (vertical), or flatter, where ever possible. There may be some isolated locations where right-of-way limitations prohibit the use of 3 (horizontal) to 1 (vertical), or flatter, side slopes and where steeper side slopes may be required. Embankments with side slopes that are steeper than 3 (horizontal) to 1 (vertical) should be suitably protected with erosion control measures compatible with the inclination of the slope, however, in no case should an embankment slope be steeper than 2 (horizontal) to 1 (vertical) unless additional soil reinforcement (i.e. geotextiles and riprap) is implemented.

It is important that all earth fill that is placed adjacent to the existing roadway embankments be carefully benched into the existing embankments in accordance with INDOT Standard Specifications Section 203.21 in order to preclude a weak zone from forming at the interface between the existing embankment soils and the new fill soil. All earthwork should be performed in accordance with current INDOT Standard Specifications.

6 GENERAL CONSTRUCTION PROCEDURES AND RECOMMENDATIONS

Since this investigation identified actual subsurface conditions only at the test boring locations, it was necessary for our geotechnical engineers to extrapolate these conditions in order to characterize the entire project site. Even under the best of circumstances, the conditions encountered during construction can be expected to vary somewhat from the test boring results and may, in the extreme case, differ to the extent that modifications to the recommendations become necessary. Therefore, we recommend that ATC be retained as geotechnical consultant through the earth-related phases of this project to correlate actual soil conditions with test boring data, identify variations, conduct additional tests that may be needed and recommend solutions to earth-related problems that may develop.

6.1 Site Preparation and Earthwork

Any topsoil, as well as any wet, soft or otherwise unsuitable surficial bearing soils should be stripped from the project site within the construction limits prior to construction of the roadway subgrade and pavement. Proofrolling of the foundation soils shall be performed in accordance with the INDOT Standard Specifications, Section 203.26 within all areas where new fill or pavement will be placed. Care should be exercised during grading operations at the site. Due to the nature of the near-surface soils, the traffic of heavy equipment, including heavy compaction equipment, may create pumping and general deterioration of the shallower soils, especially if excess surface water is present. The grading, therefore, should be done during a dry season, if possible.

It is suggested that an undistributed quantity of embankment foundation soil improvement (i.e., removal and replacement with crushed limestone on geogrid) equal to approximately 40 percent of the new or widened embankment area should be included in the contract to be used where determined to be necessary in order to provide a suitable foundation upon which to construct embankments. However, due to the variable subsurface conditions that may vary dramatically over relatively short distances, it is emphasized that this quantity should be considered strictly for planning purposes only and should not be considered to be definitive or absolute. The actual areas requiring embankment foundation improvement will need to be determined in the field at the time of construction based upon the actual condition of the soils exposed at the specific locations and the specific time. The actual extent/magnitude of foundation improvement will depend to a large extent upon weather conditions, the construction schedule, sequencing of the earthwork and the methods and procedures utilized by the earthwork contractor.

6.2 Open Excavations and Trenches

It is recommended that wherever disturbed granular soils in the base of excavations are encountered, they be compacted with vibratory equipment to 98% of the maximum dry density in accordance with ASTM D-698 (Standard Proctor).

Many factors influence the performance of excavations during construction. Soil type, excavation slopes, weather conditions, groundwater level, and construction procedures are the most influential of these factors. At no time should excavations be expected to stand vertically without lateral bracing. Additionally, excavated spoil materials should not be placed near the excavation slope. Excavations should be adequately braced to prevent damage to the structure, to adjacent structures, utilities, pavements or walks, and to prevent injury to workmen or others. Applicable OSHA guidelines should be followed at all times.

The shallow cohesive soils encountered across this site are typically described as Type B soils in the OSHA Construction Standards for Excavations. Therefore, it will be necessary to maintain all construction slopes at 1:1 (H:V) or shallower, unless sandy soils are encountered. However, some softer soils or unsuitable fill material or disturbed soils may be encountered across portions of the site, which require undercutting. If during the excavation, it is determined that the soils are not stable on a 1:1 slope, it will be necessary to flatten the slope to a maximum of 1½:1. At this construction slope, excavations are limited to twenty (20) feet deep or less. At no time should spoil material be placed next to the excavation. Trench boxes may also be considered to hold back the slopes of the excavations. Care must be taken not to undermine the existing structures or roadway.

6.3 Bedrock Considerations

It should be noted that the bedrock surface varied greatly across the project site. Auger refusal was encountered at elevations ranging from El. 789 ft. to El. 807 ft. Rock cores conducted at test boring locations indicated competent bedrock. Based upon our experience in Bloomington, Indiana, isolated “floaters” must be anticipated.

It is anticipated that utility line excavations and other related site activities will encounter bedrock. Rock excavation is expensive and should be carefully considered when final elevations are selected. The nature of the bedrock is such that blasting, ripping, or jack hammering may be necessary for removal.

The elevation to sound rock shown on the boring logs should be used only as a guide. The weathering of rock is a transitional process. The degree of weathering usually decreases nonuniformly with depth over a given area and a sharp line of demarcation does not exist between weathered and unweathered rock. Additionally, rock shelves, floaters and other features associated may be encountered. Estimates of rock excavation should consider these concerns. Typically, construction equipment encounters difficulty one (1) to two (2) feet above the depth to auger refusal.

For this reason, typically, construction equipment encounters difficulty a several inches above the elevation of probe refusal. The bedrock surface should be anticipated to vary somewhat and the borings should not be anticipated to have encountered bedrock at its highest or lowest elevation. Due to the high cost of rock excavation, it is recommended that an appropriate degree of rock excavation be anticipated.

6.4 Placement and Compaction of Engineered Fill

Engineered fill shall be placed in lift thicknesses not to exceed about 8 in. and compacted to a minimum of 95 percent of the standard Proctor maximum dry density (AASHTO T99) as specified in the current INDOT Standard Specifications. It is likely that some drying of the fill material will be required before being placed in order to meet the INDOT Specification for fill placement. It is probable that this will also be the case for most of the soil materials encountered within the range of subgrade treatment. However, adequate moisture conditioning may be difficult during wet seasons and, during such seasons, a granular material may be necessary to satisfy the minimum compaction requirements.

Where fill material is placed on existing slopes, benches should be cut into the existing slopes so as to preclude a shear plane from developing at the interface. Benches having a minimum width of 10 ft should be cut into the natural slopes and existing embankment side slopes that are 4 (horizontal) to 1 (vertical), or steeper, before new engineered fill is placed. These benches should be excavated in accordance with Section 203.21 of the INDOT Standard Specifications.

6.5 Erosion Control

Highly erodible, granular material (such as structure backfill) shall not be used in proposed ditches or within 12 in. of the required final grade of side slopes. The material used to encase the embankment shall be non-erodible, cohesive material that is free from debris and other deleterious materials and suitable for sustaining vegetation. The final slopes shall be seeded or sodded for erosion control. If seeded, the slope shall be protected with an erosion control blanket to provide for adequate seed germination and rooting.

6.6 Construction Dewatering

At the time of the field investigation, free ground water was encountered within the test borings. Depending upon seasonal conditions, some dewatering should be expected during construction. In excavations that are made in cohesive soils, the ground water can likely be removed by pumping from sumps. However, in cases where a saturated sand or silt layer is encountered in the base of the excavation, it will not be possible to pump water directly from the base of the excavation without causing deterioration of the subgrade soil. In this case, it will be necessary to pump from a sump located adjacent to the excavation or to depress the ground water using wells or well points. The best dewatering system for each case must be determined at the time of construction based upon actual field conditions. The dewatering plan shall be submitted by the Contractor and approved by the Engineer.

7 LIMITATIONS OF STUDY

An inherent limitation of any geotechnical engineering study is that conclusions must be drawn on the basis of data collected at a limited number of discrete locations. The recommendations provided in this report were developed from the information obtained from the test borings that depict subsurface conditions only at these specific locations and at the particular time designated on the logs. Soil conditions at other locations may differ from conditions occurring at these boring locations. The nature and extent of variations between the borings may not become evident until the course of construction. If variations then appear evident, it will be necessary to re-evaluate the recommendations of this report after performing on-site observations during the excavation period and noting the characteristics of any variation.

Our professional services have been performed, our findings obtained and our recommendations prepared in accordance with customary principles and practices in the field of geotechnical engineering at the time when the services were performed and at the location where the services were performed. This warranty is in lieu of all other warranties either express or implied. This company is not responsible for the independent conclusions, opinions or recommendations made by others based on the field exploration and laboratory test data presented in this report.

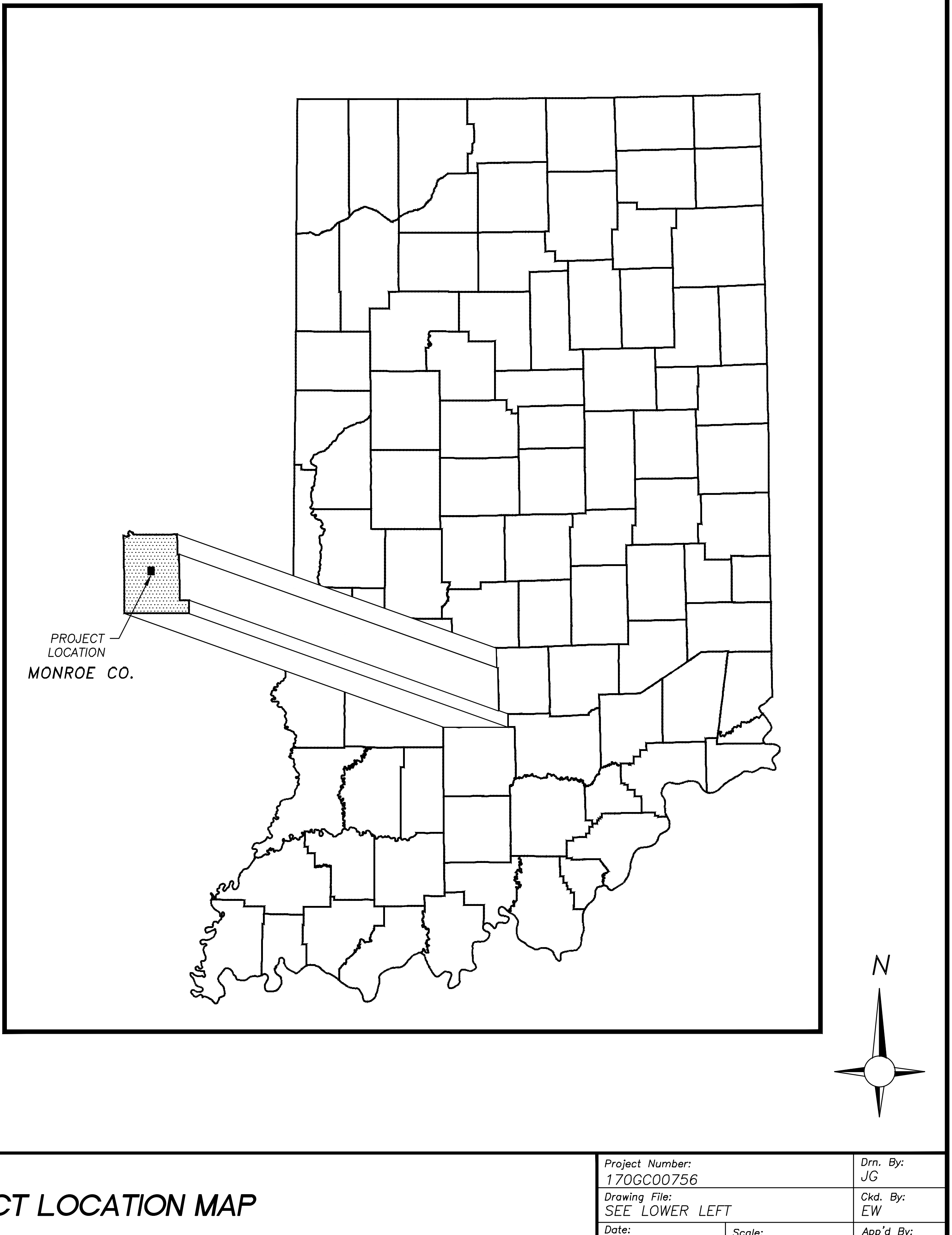
The scope of our services does not include any environmental assessment or investigation for the presence or absence of hazardous or toxic materials in the soil, ground water or surface water within or beyond the site studied.

ATC assumes no responsibility for any construction procedures, temporary excavations (including utility trenches), temporary dewatering or site safety during or after construction. The contractor will be solely responsible for all construction procedures, construction means and methods, construction sequencing and for safety measures during construction. All applicable federal, state and local laws and regulations regarding construction safety must be followed, including current Occupational Safety and Health Administration (OSHA) Regulations including OSHA 29 CFR Part 1926 “Safety and Health Regulations for Construction”, Subpart P “Excavations”, and/or successor regulations. The Contractor is solely responsible for designing and constructing stable, temporary excavations and should brace, shore, slope, or bench the sides of the excavations as necessary to maintain stability of the excavation sides and bottom.

Appendices

APPENDIX A

PROJECT LOCATION MAP – Figure 1
VICINITY MAP – Figure 2
BORING PLAN – Figures 3 & 4



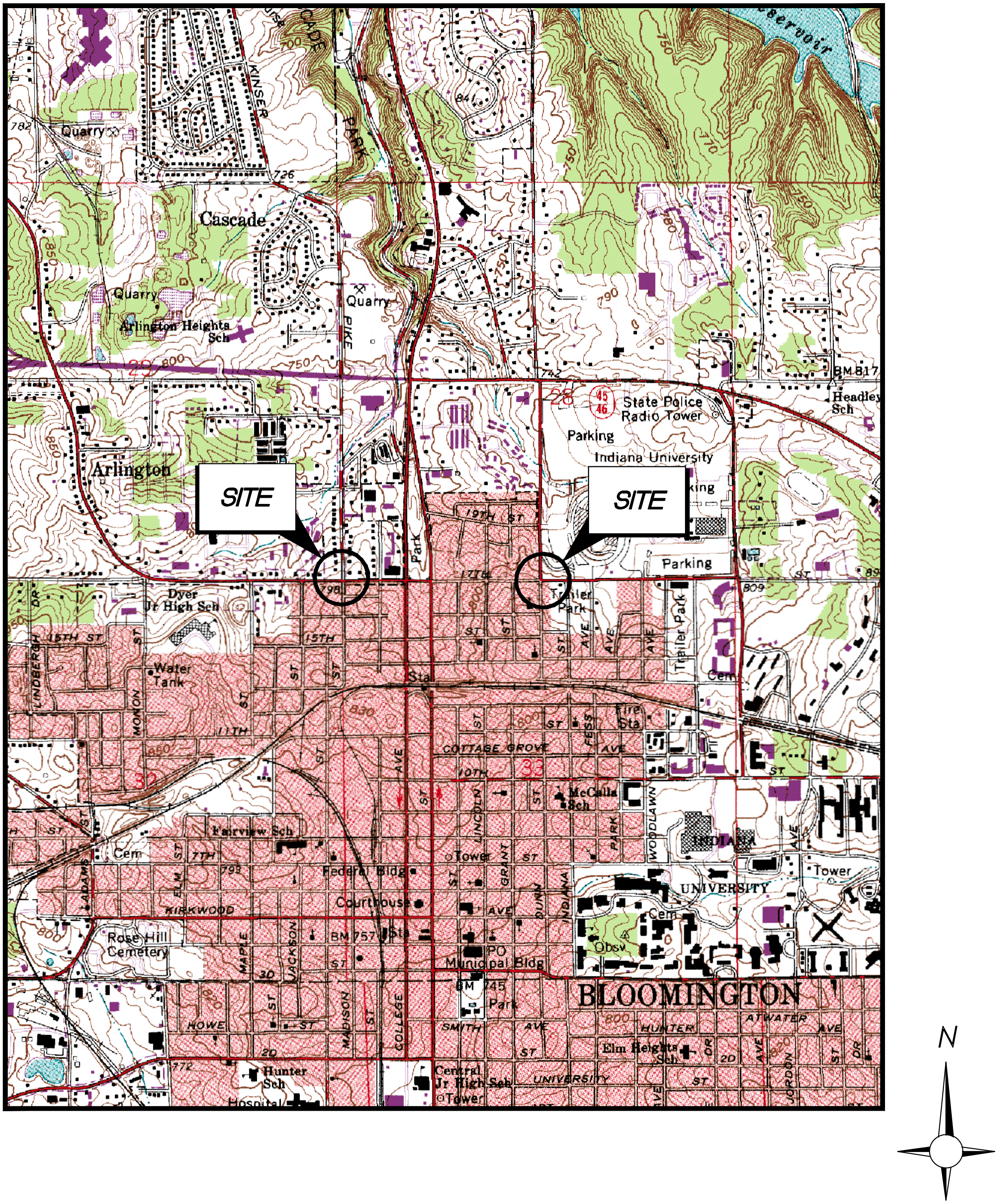
PROJECT LOCATION MAP

BLOOMINGTON INTERSECTION IMPROVEMENTS
17th STREET AND KINSER STREET
BLOOMINGTON, INDIANA

Project Number: 170GC00756
Drawing File: SEE LOWER LEFT
Date: 2/19
Scale: NOT TO SCALE
Drn. By: JG
Ckd. By: EW
App'd By:
Figure: 1

ATC

H:\2019\LOCHMUELLER GROUP\170TH ST INTERSECTION IMPROVEMENTS\GEO TECH\170GC00756-VIC.DWG, PROJ

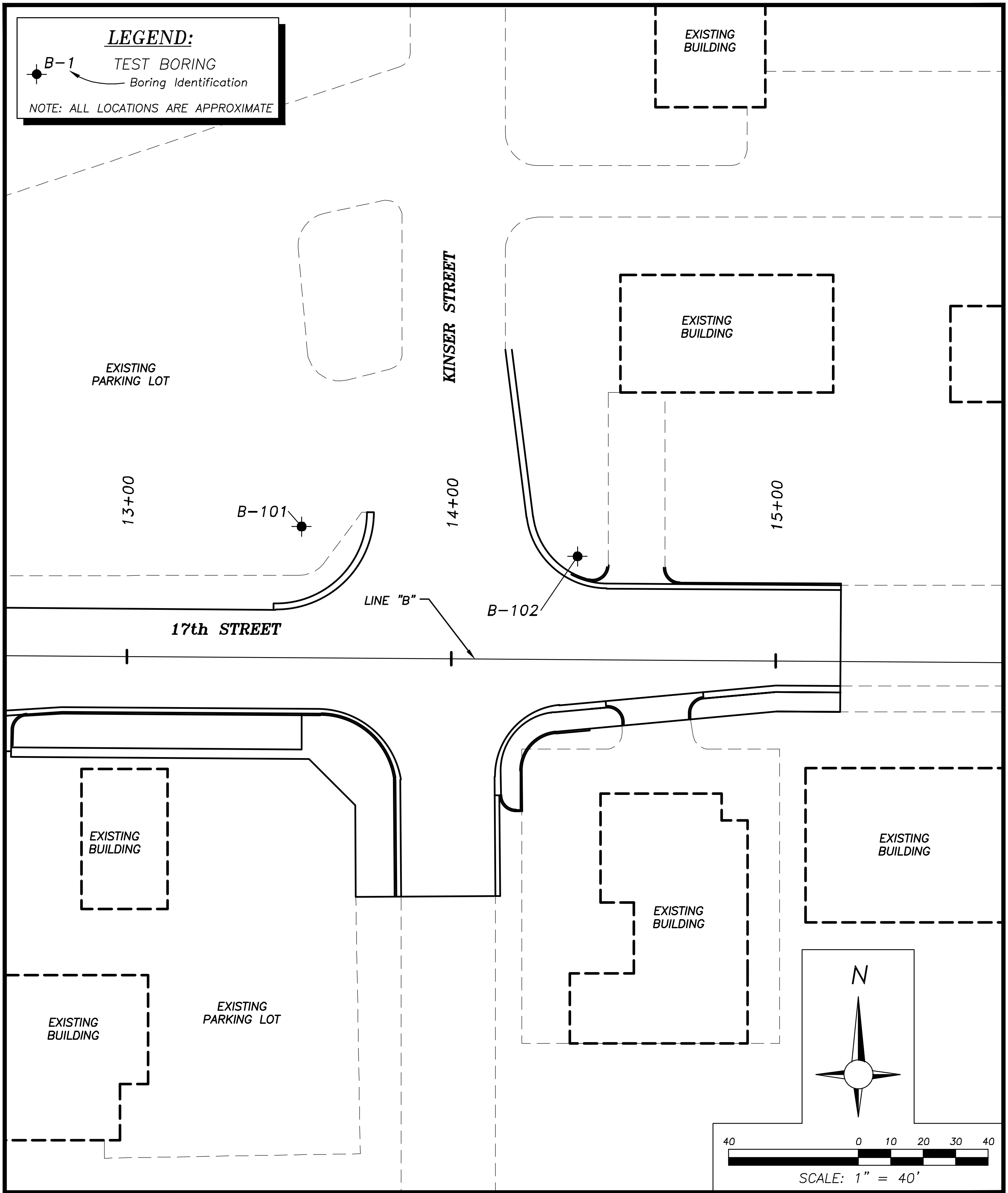


VICINITY MAP

BLOOMINGTON INTERSECTION IMPROVEMENTS
17th STREET AND KINSER STREET
BLOOMINGTON, INDIANA

Project Number: 170GC00756		Drn. By: JG
Drawing File: SEE LOWER LEFT		Ckd. By: EW
Date: 2/19	Scale: 1"=2,000'	App'd By:
		Figure: 2

H:\2019\LOCHMUELLER GROUP\170TH ST INTERSECTION IMPROVEMENTS\GEO TECH\170GC00756-VIC.DWG, VIC

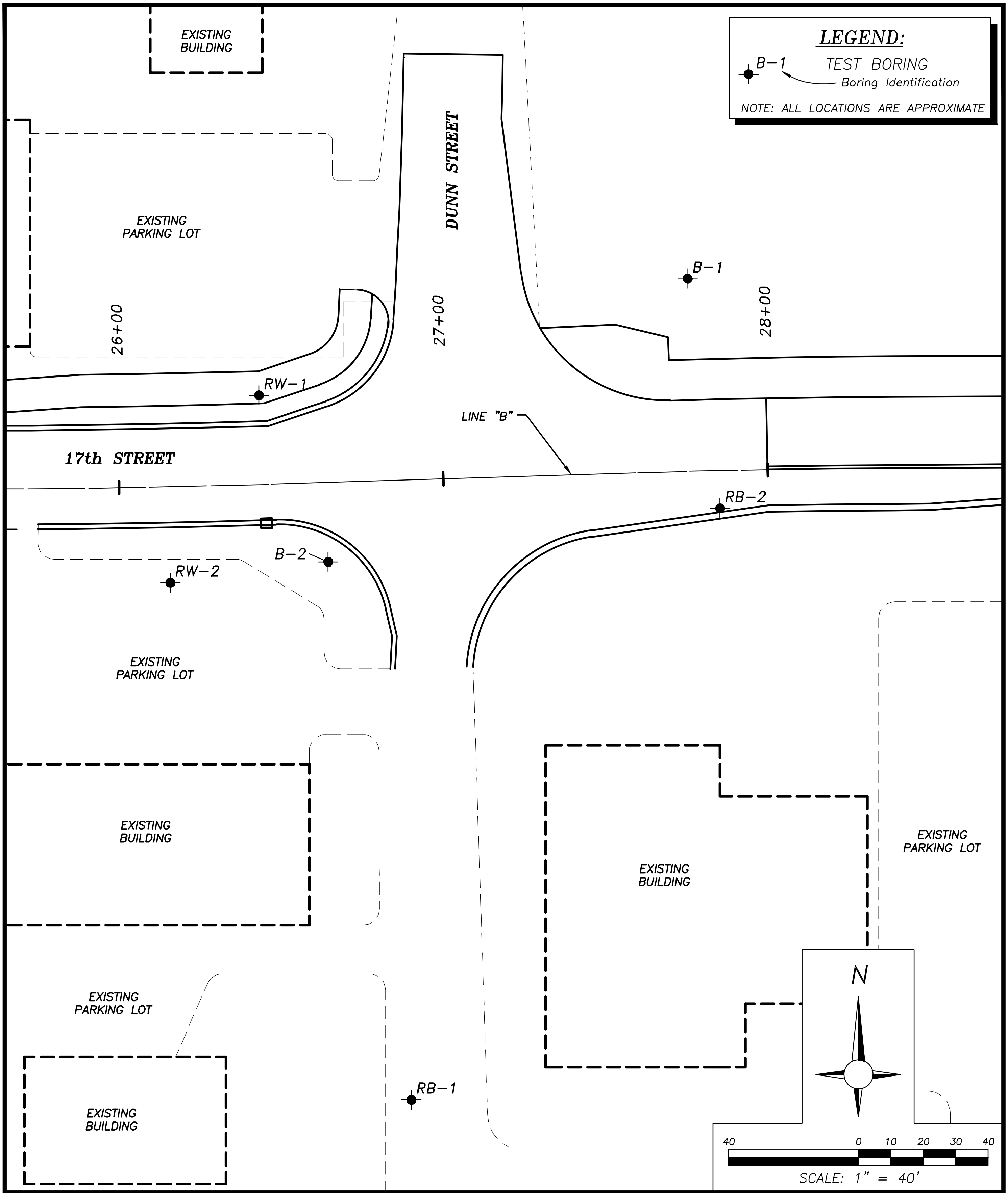


BORING PLAN

BLOOMINGTON INTERSECTION IMPROVEMENTS
17th STREET AND KINSER STREET
BLOOMINGTON, INDIANA

Project Number: 170GC00756
Drawing File: SEE LOWER LEFT
Date: 2/19
Scale: AS SHOWN
Drn. By: JG
Ckd. By: EW
App'd By:
Figure: 3

H:\2019\LOCHMUELLER GROUP\170TH ST INTERSECTION IMPROVEMENTS\GEO TECH\170GC00756-BPLAN.DWG, BPLAN



BORING PLAN

BLOOMINGTON INTERSECTION IMPROVEMENTS
17th STREET AND DUNN STREET
BLOOMINGTON, INDIANA

Project Number: 170GC00756	Drn. By: JG
Drawing File: SEE LOWER LEFT	Ckd. By: EW
Date: 2/19	Scale: AS SHOWN
	App'd By:
	Figure: 4

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APPENDIX B

FIELD CLASSIFICATION SYSTEM FOR SOIL EXPLORATION
TEST BORING LOGS

FIELD CLASSIFICATION SYSTEM FOR SOIL EXPLORATION

NON-COHESIVE SOILS

(Silt, Sand, Gravel and Combinations)

Density

Very Loose - 5 blows/ft or less
Loose - 6 to 10 blows/ft
Medium Dense - 11 to 30 blows/ft
Dense - 31 to 50 blows/ft
Very Dense - 51 blows/ft or more

Relative Proportions

Descriptive Term	Percent
Trace	1 - 10
Little	11 - 20
Some	21 - 35
And	36 - 50

Particle Size Identification

Boulders - 8 inch diameter or more
Cobbles - 3 to 8 inch diameter
Gravel - Coarse - 1 to 3 inch
Medium - ½ to 1 inch
Fine - ¼ to ½ inch
Sand - Coarse 2.00mm to ¼ inch (dia. of pencil lead)
Medium 0.42 to 2.00mm (dia. of broom straw)
Fine 0.074 to 0.42mm (dia. of human hair)
Silt 0.074 to 0.002mm (cannot see particles)

COHESIVE SOILS

(Clay, Silt and Combinations)

Consistency

Very Soft - 3 blows/ft or less
Soft - 4 to 5 blows/ft
Medium Stiff - 6 to 10 blows/ft
Stiff - 11 to 15 blows/ft
Very Stiff - 16 to 30 blows/ft
Hard - 31 blows/ft or more

Plasticity

Degree of Plasticity	Plasticity Index
None to slight	0 - 4
Slight	5 - 7
Medium	8 - 22
High to Very High	over 22

Classification on the logs are made by visual inspection of samples.

Standard Penetration Test — Driving a 2.0" O.D. 1-3/8" I.D. sampler a distance of 1.0 foot into undisturbed soil with a 140 pound hammer free falling a distance of 30 inches. It is customary for ATC to drive the spoon 6 inches to seat into undisturbed soil, then perform the test. The number of hammer blows for seating the spoon and making the test are recorded for each 6 inches of penetration on the drill log (Example — 6-8-9). The standard penetration test result can be obtained by adding the last two figures (i.e., 8 + 9 = 17 blows/ft). (ASTM D-1586-11).

Strata Changes — In the column "Soil Descriptions" on the drill log the horizontal lines represent strata changes. A solid line (______) represents an actually observed change. A dashed line (_ _ _ _ _ _) represents an estimated change.

Ground Water observations were made at the times indicated. Porosity of soil strata, weather conditions, site topography, etc., may cause changes in the water levels indicated on the logs.

ATC
ENVIRONMENTAL • GEOTECHNICAL
BUILDING SCIENCES • MATERIALS TESTING

Revised 1/16

Boring Log

BORING NO.: **B-101**
SHEET 1 OF 2
GEOTECHNICAL CONSULTANT : ATC Group Services LLC
LATITUDE : 39.17913
DES NO. : NA
STRUCTURE #: Kinser Pike
LONGITUDE : -86.53791
PROJECT TYPE: Intersection Improvements
DATUM : NAD83
LOCATION : 17th Street at Dunn St. & 17th Street at Kinser Pike
DATE STARTED : 02-13-19
COUNTY : Monroe
PROJECT NO.: 170GC00756
DATE COMPLETED : 02-13-19

ELEVATION : 796.0
STATION : 13+54
OFFSET : 41.0 ft Left
LINE : "'B'"
DEPTH : 11.3 ft

BORING METHOD : Hollow Stem Auger
RIG TYPE : B-57 Truck
CASING DIA. : 2
CORE SIZE : 6

HAMMER : Auto
DRILLER/INSP : G. Lauber/J. Evans
TEMPERATURE : 40 °F
WEATHER : Sunny

GROUNDWATER: ▽ Encountered at 5.5 ft ▼ At completion 3.5 ft ☒ Caved in at 6.7 ft

ELEVATION	SAMPLE DEPTH	SOIL/MATERIAL DESCRIPTION	SAMPLE NUMBER	SPT per 6"	% RECOVERY	MOISTURE CONTENT	DRY DENSITY, pcf	POCKET PEN., tsf	UNCONF. COMP., tsf	ATTERBERG LIMITS LL	PL	PI	REMARKS
		Asphalt 3 inches 0.3											0.0, Ground surface elevation estimated from Google Earth
795.0		**Crushed Stone** 6 inches 0.8											
	2.5	**Silty Clay Loam A-7-6(32)**, Brown, moist, medium stiff to soft, (Lab No. 1) *Large Rocks at 3.5ft*	SS1	2-3-3	78	29.6		0.5		47	16	31	
	5.0		SS2	3-2-3	78	27.6		0.5					
790.0		6.0 6.3 **Silty Clay Loam** Light brown, wet, hard residual soil, (Lab No. Visual)	SS3	50/0.2	83								6.3, Auger Refusal at 6.3 ft.
	7.5 10.0	**Limestone** Gray, slightly weathered	RC1 RQD= 80%		90								
785.0		11.3											11.3, Boring backfilled in accordance with INDOT Aquifer Protection Guidelines. Pavement patched.
780.0	12.5 15.0 17.5 20.0	Bottom of Boring at 11.3 ft											

Continued on next page

PHOTOS

Figure B-101.1
Limestone
Run #1; 6.3 ft to 11.3 ft; Recovery = 90%; RQD = 80%

Boring Log

BORING NO.: **B-102**
SHEET 1 OF 2
LATITUDE : 39.17910
LONGITUDE : -86.53761
DATUM : NAD83
DATE STARTED : 02-26-19
DATE COMPLETED : 02-26-19

GEOTECHNICAL CONSULTANT : ATC Group Services LLC
DES NO. : NA
STRUCTURE #: Kinser Pike
PROJECT TYPE: Intersection Improvements
LOCATION : 17th Street at Dunn St. & 17th Street at Kinser Pike
COUNTY : Monroe
PROJECT NO.: 170GC00756

ELEVATION : 797.0
STATION : 14+38
OFFSET : 32.0 ft Left
LINE : '"B"'
DEPTH : 13.1 ft

BORING METHOD : Hollow Stem Auger
RIG TYPE : D-50T ATV
CASING DIA. : 2
CORE SIZE : 6

HAMMER : Auto
DRILLER/INSP : J. Cook/J. Evans
TEMPERATURE : 40 °F
WEATHER : Sunny

GROUNDWATER: ∇ Encountered at None ▼ At completion None ▨ Caved in at 3.5 ft

ELEVATION	SAMPLE DEPTH	SOIL/MATERIAL DESCRIPTION	SAMPLE NUMBER	SPT per 6"	% RECOVERY	MOISTURE CONTENT	DRY DENSITY, pcf	POCKET PEN., tsf	UNCONF. COMP., tsf	ATTERBERG LIMITS LL	PL	PI	REMARKS
797.0	0.2	**Topsoil** 2 inches											0.0, Ground surface elevation estimated from Google Earth
		Silty Clay Loam A-7-6, Brown and orange, moist, medium stiff, (Lab No. 1)	SS1	2-3-4	67	25.6		1.5					
			SS2	2-3-4	67	27.4		1.0					
			SS3	2-3-5	78	26.7		2.0					
	7.8		SS4	50/0.1	8333								7.8, Auger Refusal at 7.8 ft.
		Limestone Gray, slightly weathered	RC1 RQD= 100%		100								
	13.1		RC1 RQD= 45%		65								13.0, Loss of water return at 13.0 ft. 13.1, Boring backfilled in accordance with INDOT Aquifer Protection Guidelines.
		Bottom of Boring at 13.1 ft											

Continued on next page

Boring Log

BORING NO.: **B-102**
SHEET 2 OF 2
GEOTECHNICAL CONSULTANT : ATC Group Services LLC
LATITUDE : 39.17910
DES NO. : NA
STRUCTURE #: Kinser Pike
LONGITUDE : -86.53761
PROJECT TYPE: Intersection Improvements
DATUM : NAD83

PHOTOS

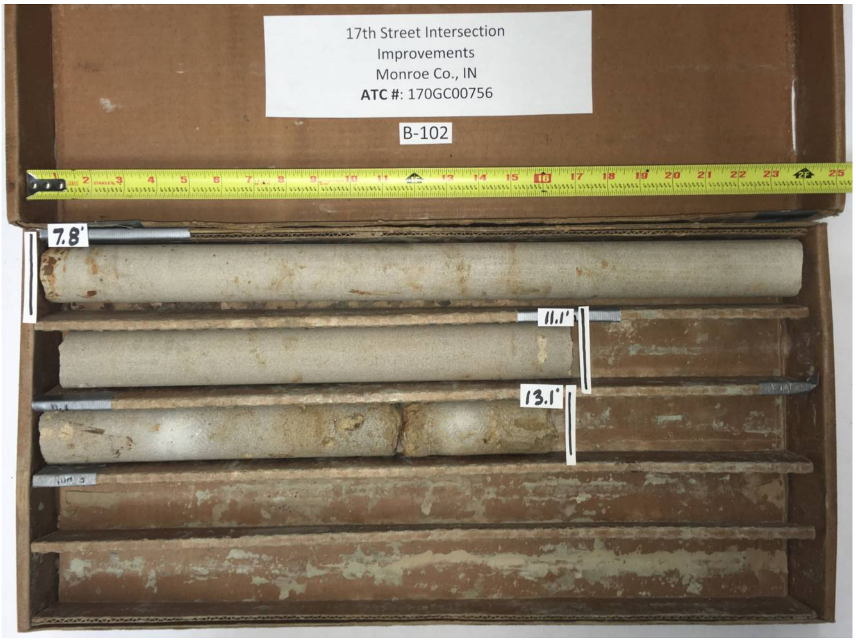

Figure B-102.1
Limestone
Run #1; 7.8 ft to 11.1 ft; Recovery = 100%; RQD = 100%
Run #2; 11.1 ft to 13.1 ft; Recovery = 65%; RQD = 45%
*Loss of water return at 13 ft

Boring Log

BORING NO.: **B-1**
SHEET 1 OF 2
LATITUDE : 39.17916
LONGITUDE : -86.52806
DATUM : NAD83
DATE STARTED : 02-26-19
DATE COMPLETED : 02-26-19

GEOTECHNICAL CONSULTANT : ATC Group Services LLC
DES NO. : NA
STRUCTURE #: Dunn Street
PROJECT TYPE: Intersection Improvements
LOCATION : 17th Street at Dunn St. & 17th Street at Kinser Pike
COUNTY : Monroe
PROJECT NO.: 170GC00756

ELEVATION : 802.0
STATION : 27+74
OFFSET : 59.0 ft Left
LINE : "'B'"
DEPTH : 13.8 ft

BORING METHOD : Hollow Stem Auger
RIG TYPE : B-57 Truck
CASING DIA. : 2
CORE SIZE : 6

HAMMER : Auto
DRILLER/INSP : J. Cook/J. Evans
TEMPERATURE : 40 °F
WEATHER : Sunny

GROUNDWATER: ∇ Encountered at None ▼ At completion 2.7 ft ▨ Caved in at 7.5 ft

ELEVATION	SAMPLE DEPTH	SOIL/MATERIAL DESCRIPTION	SAMPLE NUMBER	SPT per 6"	% RECOVERY	MOISTURE CONTENT	DRY DENSITY, pcf	POCKET PEN., tsf	UNCONF. COMP., tsf	ATTERBERG LIMITS LL	PL	PI	REMARKS
		Topsoil 3 inches 0.3											0.0, Ground surface elevation estimated from Google Earth
			SS1	8-6-6	100	23.3		4.0					
800.0													
	▼ 2.5	**Silty Clay Loam A-7-6**, Reddish brown, moist, stiff, (Lab No. 1)								64	17	47	
			SS2	4-5-6	67	24.8		2.5					
	5.0	5.5											
		Silty Clay Loam A-7-6, Brown, moist, very stiff, Residual Soil, (Lab No. Visual)	SS3	30-36-50/0.2	42								
795.0													
	▨ 7.5	7.6											7.6, Auger Refusal at 7.6 ft
			RC1 RQD= 60%		76								
	10.0												
		Limestone Gray, slightly weathered											
790.0													
	12.5		RC2 RQD= 95%		95								
		13.8											13.8, Boring backfilled in accordance with INDOT Aquifer Protection Guidelines
		Bottom of Boring at 13.8 ft											
	15.0												
785.0													
	17.5												
	20.0												

ATC STATE LOG_PHOTOS GC00756.GPJ INDOT TEMPLATE.GDT 5/2/19

Continued on next page

Boring Log

GEOTECHNICAL CONSULTANT : ATC Group Services LLC

DES NO. : NA STRUCTURE #: Dunn Street

PROJECT TYPE: Intersection Improvements

BORING NO.: **B-1**

SHEET 2 OF 2

LATITUDE : 39.17916

LONGITUDE : -86.52806

DATUM : NAD83

PHOTOS

Figure B-1.1
Limestone
Run #1: 7.6 ft to 11.8 ft; Recovery = 76%; RQD = 60%
Run #2: 11.8 ft to 13.8 ft; Recovery = 95%; RQD = 95%

Boring Log

BORING NO.: **B-2**
SHEET 1 OF 2
GEOTECHNICAL CONSULTANT : ATC Group Services LLC
LATITUDE : 39.17892
DES NO. : NA
STRUCTURE #: Dunn Street
LONGITUDE : -86.52846
PROJECT TYPE: Intersection Improvements
DATUM : NAD83
LOCATION : 17th Street at Dunn St. & 17th Street at Kinser Pike
DATE STARTED : 02-13-19
COUNTY : Monroe
PROJECT NO.: 170GC00756
DATE COMPLETED : 02-13-19

ELEVATION : 809.0
STATION : 26+63
OFFSET : 24.0 ft Right
LINE : "'B"'
DEPTH : 9.3 ft
BORING METHOD : Hollow Stem Auger
RIG TYPE : B-57 Truck
CASING DIA. : 2
CORE SIZE : 6
HAMMER : Auto
DRILLER/INSP : G. Lauber/J. Evans
TEMPERATURE : 40 °F
WEATHER : Sunny

GROUNDWATER: ▽ Encountered at None ▼ At completion 3.9 ft ⊠ Caved in at 7.6 ft

ELEVATION	SAMPLE DEPTH	SOIL/MATERIAL DESCRIPTION	SAMPLE NUMBER	SPT per 6"	% RECOVERY	MOISTURE CONTENT	DRY DENSITY, pcf	POCKET PEN., tsf	UNCONF. COMP., tsf	ATTERBERG LIMITS LL	PL	PI	REMARKS
		Asphalt 8 inches 0.7											0.0, Ground surface elevation estimated from Google Earth
	2.5	**Silty Clay Loam A-7-6**, Brown, moist, medium stiff, (Lab No. 1) 3.0	SS1	3-3-3	100	25.4		1.0					
805.0 ▼	5.0	**Silty Clay Loam A-7-6**, Reddish brown, moist, soft to medium stiff, (Lab No. 1)	SS2	2-2-3	100	26.7		1.5		50	22	28	
⊠	7.5	8.0	SS3	3-3-3	100	34.2		2.0					
800.0		**Silty Clay Loam A-7-6**, Brown, moist, hard, (Lab No. 1) 9.3	SS4	3-50/0.2	95	40.9		1.0					9.3, Auger Refusal at 9.3 ft.
795.0	10.0 12.5	**Limestone** Gray, slightly weathered 14.3	RC1 RQD= 100%		100								
790.0	15.0 17.5 20.0	Bottom of Boring at 9.3 ft											14.3, Boring backfilled in accordance with INDOT Aquifer Protection Guidelines. Pavement patched.

Continued on next page

Boring Log

GEOTECHNICAL CONSULTANT : ATC Group Services LLC

DES NO. : NA STRUCTURE #: Dunn Street

PROJECT TYPE: Intersection Improvements

BORING NO.: **B-2**

SHEET 2 OF 2

LATITUDE : 39.17892

LONGITUDE : -86.52846

DATUM : NAD83

PHOTOS

Figure B-2.1
Limestone
Run #1; 9.3 ft to 14.3 ft; Recovery = 100%; RQD = 100%

Boring Log

GEOTECHNICAL CONSULTANT : ATC Group Services LLC
DES NO. : NA
STRUCTURE #: Dunn Street
PROJECT TYPE: Intersection Improvements
LOCATION : 17th Street at Dunn St. & 17th Street at Kinser Pike
COUNTY : Monroe
PROJECT NO.: 170GC00756

BORING NO.: **RB-1**
SHEET 1 OF 1
LATITUDE : 39.17846
LONGITUDE : -86.52837
DATUM : NAD83
DATE STARTED : 02-13-19
DATE COMPLETED : 02-13-19

ELEVATION : 821.0
STATION : 26+88
OFFSET : 191.0 ft Right
LINE : '"B"'
DEPTH : 18.7 ft

BORING METHOD : Hollow Stem Auger
RIG TYPE : B-57 Truck
CASING DIA. : 2
CORE SIZE : 6

HAMMER : Auto
DRILLER/INSP : G. Lauber/J. Evans
TEMPERATURE : 40 °F
WEATHER : Sunny

GROUNDWATER: ▽ Encountered at None ▼ At completion None ▨ Caved in at 16.4 ft

ELEVATION	SAMPLE DEPTH	SOIL/MATERIAL DESCRIPTION	SAMPLE NUMBER	SPT per 6"	% RECOVERY	MOISTURE CONTENT	DRY DENSITY, pcf	POCKET PEN., tsf	UNCONF. COMP., tsf	ATTERBERG LIMITS LL	PL	PI	REMARKS
		Asphalt 12 inches											0.0, Ground surface elevation estimated from Google Earth
820.0	1.0	**Silty Clay Loam A-7-6**, Brown, moist, medium stiff, (Lab No. 1)	SS1	3-4-5	100	27.2		1.5					
	2.5	**Silty Clay Loam A-7-6**, Reddish brown, moist, stiff to very stiff, (Lab No. 1)	SS2	5-5-6	100	26.6		1.0					
			SS3	5-6-6	100	24.8		1.0		44	19	25	
815.0			SS4	6-7-9	100	27.1		3.0					
			SS5	3-5-6	100	38.2		1.5					
810.0	10.5	**Clay A-7-5**, Brown, moist, soft, (Lab No. Visual)	SS6	1-2-3	100	68.3		<0.25		141	28	113	11.0, SS6: LOI=6%; Ca/Mg=6.9%
	13.0	**Silty Clay Loam A-7-6**, Brown, moist, hard, residual soil, (Lab No. 1)											
	13.5	**Limestone** Gray, highly weathered	SS7	3-25-50	72								
805.0			SS8	50/0.2	83								
	18.7		SS9	50/0.2	83								18.7, Boring backfilled in accordance with INDOT Aquifer Protection Guidelines. Pavement patched.
800.0		Bottom of Boring at 18.7 ft											

Boring Log

BORING NO.: **RB-2**
SHEET 1 OF 2
GEOTECHNICAL CONSULTANT : ATC Group Services LLC
LATITUDE : 39.17896
DES NO. : NA
STRUCTURE #: Dunn Street
LONGITUDE : -86.52803
PROJECT TYPE: Intersection Improvements
DATUM : NAD83
LOCATION : 17th Street at Dunn St. & 17th Street at Kinser Pike
DATE STARTED : 02-13-19
COUNTY : Monroe
PROJECT NO.: 170GC00756
DATE COMPLETED : 02-13-19

ELEVATION : 806.0
STATION : 27+83
OFFSET : 11.0 ft Right
LINE : "'B"'
DEPTH : 15.0 ft
BORING METHOD : Hollow Stem Auger
RIG TYPE : B-57 Truck
CASING DIA. : 2
CORE SIZE : 6
HAMMER : Auto
DRILLER/INSP : G. Lauber/J. Evans
TEMPERATURE : 40 °F
WEATHER : Sunny

GROUNDWATER: ▽ Encountered at None ▼ At completion 4.0 ft ▨ Caved in at 8.5 ft

ELEVATION	SAMPLE DEPTH	SOIL/MATERIAL DESCRIPTION	SAMPLE NUMBER	SPT per 6"	% RECOVERY	MOISTURE CONTENT	DRY DENSITY, pcf	POCKET PEN., tsf	UNCONF. COMP., tsf	ATTERBERG LIMITS LL	PL	PI	REMARKS
		Topsoil 6 inches 0.5											0.0, Ground surface elevation estimated from Google Earth
805.0		**Silty Clay Loam A-7-6**, Brown, moist, medium stiff to stiff, (Lab No. 1)	SS1	2-4-5	100	18.6		1.0					
	2.5	3.0	SS2	10-7-5	67	22.7		3.0					
	5.0	**Silty Clay Loam A-7-6**, Reddish brown, moist, stiff, (Lab No. 1)	SS3	7-7-7	100	27.2		1.0					
800.0	7.5	8.0	SS4	5-5-8	100	28.4		3.5					
		Silty Clay Loam A-7-6, Reddish brown, moist, hard, residual soil, (Lab No. Visual) 10.0	SS5	50/0.3	83								
795.0	10.0 12.5	**Limestone** Gray 15.0	RC1 RQD= 95%		100								10.0, Auger Refusal at 10 ft.
790.0	15.0 17.5 20.0	Bottom of Boring at 15.0 ft											15.0, Boring backfilled in accordance with INDOT Aquifer Protection Guidelines

Continued on next page

Boring Log

BORING NO.: **RB-2**
SHEET 2 OF 2
GEOTECHNICAL CONSULTANT : ATC Group Services LLC
LATITUDE : 39.17896
DES NO. : NA
STRUCTURE #: Dunn Street
LONGITUDE : -86.52803
PROJECT TYPE: Intersection Improvements
DATUM : NAD83

PHOTOS

Figure RB-2.1
Limestone
Run #1; 10 ft. to 15 ft.; Recovery = 100%; RQD = 95%

Boring Log

BORING NO.: **RW-1**
SHEET 1 OF 2
GEOTECHNICAL CONSULTANT : ATC Group Services LLC
LATITUDE : 39.17906
DES NO. : NA
STRUCTURE #: Dunn Street
LONGITUDE : -86.52853
PROJECT TYPE: Intersection Improvements
DATUM : NAD83
LOCATION : 17th Street at Dunn St. & 17th Street at Kinser Pike
DATE STARTED : 02-26-19
COUNTY : Monroe
PROJECT NO.: 170GC00756
DATE COMPLETED : 02-26-19

ELEVATION : 807.5
STATION : 26+41
OFFSET : 27.0 ft Left
LINE : '"B"'
DEPTH : 13.5 ft
BORING METHOD : Hollow Stem Auger
RIG TYPE : D-50T ATV
CASING DIA. : 2
CORE SIZE : 6
HAMMER : Auto
DRILLER/INSP : J. Cook/J. Evans
TEMPERATURE : 40 °F
WEATHER : Sunny

GROUNDWATER: ∇ Encountered at None ▼ At completion 12.8 ft ▨ Caved in at 13.2 ft

ELEVATION	SAMPLE DEPTH	SOIL/MATERIAL DESCRIPTION	SAMPLE NUMBER	SPT per 6"	% RECOVERY	MOISTURE CONTENT	DRY DENSITY, pcf	POCKET PEN., tsf	UNCONF. COMP., tsf	ATTERBERG LIMITS LL	PL	PI	REMARKS
		Topsoil 2 inches 0.2											0.0, Ground surface elevation estimated from Google Earth
805.0	2.5	**Silty Clay Loam A-7-6**, Brown, moist, soft, (Lab No. 1) 3.0	SS1	4-2-3	67	28.6		0.5					
	5.0	**Silty Clay Loam A-7-6**, Brown and orange, moist, medium stiff to very stiff, (Lab No. 1)	SS2	2-3-3	100	24.9		1.5					
800.0	7.5		SS3	3-9-14	100	54.6		<0.25					
	10.0		SS4	2-6-3	67	41.8		1.0					
795.0	12.5	13.5	SS5	2-12-3	67	51.6		1.0					13.5, Auger Refusal at 13.5 ft.
	15.0	**Limestone** Gray, slightly weathered	RC1 RQD= 85%		94								
790.0	17.5	18.8	RC2 RQD= 85%		95								18.8, Boring backfilled in accordance with INDOT Aquifer Protection Guidelines
	20.0	Bottom of Boring at 13.5 ft											
785.0	22.5												
	25.0												

Continued on next page

Boring Log

GEOTECHNICAL CONSULTANT : ATC Group Services LLC

DES NO. : NA
STRUCTURE #: Dunn Street

PROJECT TYPE: Intersection Improvements

BORING NO.: **RW-1**
SHEET 2 OF 2
LATITUDE : 39.17906
LONGITUDE : -86.52853
DATUM : NAD83

PHOTOS

Figure RW-1.1
Limestone
Run #1; 13.5 ft to 16.8 ft; Recovery = 94%; RQD = 85%
Run #2; 16.8 ft to 18.8 ft; Recovery = 95%; RQD = 85%

Boring Log

BORING NO.: **RW-2**
SHEET 1 OF 1
LATITUDE : 39.17890
LONGITUDE : -86.52863
DATUM : NAD83
DATE STARTED : 02-13-19
DATE COMPLETED : 02-13-19

GEOTECHNICAL CONSULTANT : ATC Group Services LLC
DES NO. : NA
STRUCTURE #: Dunn Street
PROJECT TYPE: Intersection Improvements
LOCATION : 17th Street at Dunn St. & 17th Street at Kinser Pike
COUNTY : Monroe
PROJECT NO.: 170GC00756

ELEVATION : 812.0
STATION : 26+13
OFFSET : 30.0 ft Right
LINE : '"B"'
DEPTH : 13.7 ft

BORING METHOD : Hollow Stem Auger
RIG TYPE : B-57 Truck
CASING DIA. : 2
CORE SIZE : 6

HAMMER : Auto
DRILLER/INSP : G. Lauber/J. Evans
TEMPERATURE : 40 °F
WEATHER : Sunny

GROUNDWATER: ∇ Encountered at None ▼ At completion None ▨ Caved in at 8.5 ft

ELEVATION	SAMPLE DEPTH	SOIL/MATERIAL DESCRIPTION	SAMPLE NUMBER	SPT per 6"	% RECOVERY	MOISTURE CONTENT	DRY DENSITY, pcf	POCKET PEN., tsf	UNCONF. COMP., tsf	ATTERBERG LIMITS LL	PL	PI	REMARKS
		Asphalt 4 inches 0.3											0.0, Ground surface elevation estimated from Google Earth
		Crushed Stone 5 inches 0.8											1.0, Drilled location offset 8.5' East of Staked location
810.0	2.5		SS1	1-2-1	78	26.0		<0.25					
	5.0	**Silty Clay Loam A-7-6**, Brown, moist, very soft to soft, (Lab No. 1)	SS2	2-1-3	78	34.6		<0.25		46	24	22	
805.0	7.5	8.0	SS3	2-2-3	100	24.5		0.5					
	10.0	**Silty Clay Loam A-7-6**, Orangish brown, moist, stiff, (Lab No. 1) 10.5	SS4	3-5-6	100	39.4		1.5					
800.0	12.5	**Limestone** Gray	SS5	3-17-23	100								
		13.7	SS6	50/0.2	83								13.7, Auger Refusal at 13.7 ft. 13.8, Boring backfilled in accordance with INDOT Aquifer Protection Guidelines. Pavement patched.
	15.0	Bottom of Boring at 13.7 ft											
795.0	17.5												
	20.0												

APPENDIX C

SUMMARY OF CLASSIFICATION TESTS
GRAIN SIZE DISTRIBUTION TEST REPORTS
ATTERBERG LIMITS RESULTS
SUMMARY OF SPECIAL LAB TESTS

Sheet 1 of 1

Boring	Sample	Depth	Lab #	Soil Classification	Gravel %	Sand %	Silt %	Clay %	% Fines *(Passing No. 200)*	LL	PL	PI	Moisture %	LOI %	Ca/Mg %	Soluble Sulfate (ppm)	pH
B-101	SS1	1	1	A-7-6 (32) SILTY CLAY LOAM	0.3	1.4	69.6	28.7	98.3	47	16	31	29.6				

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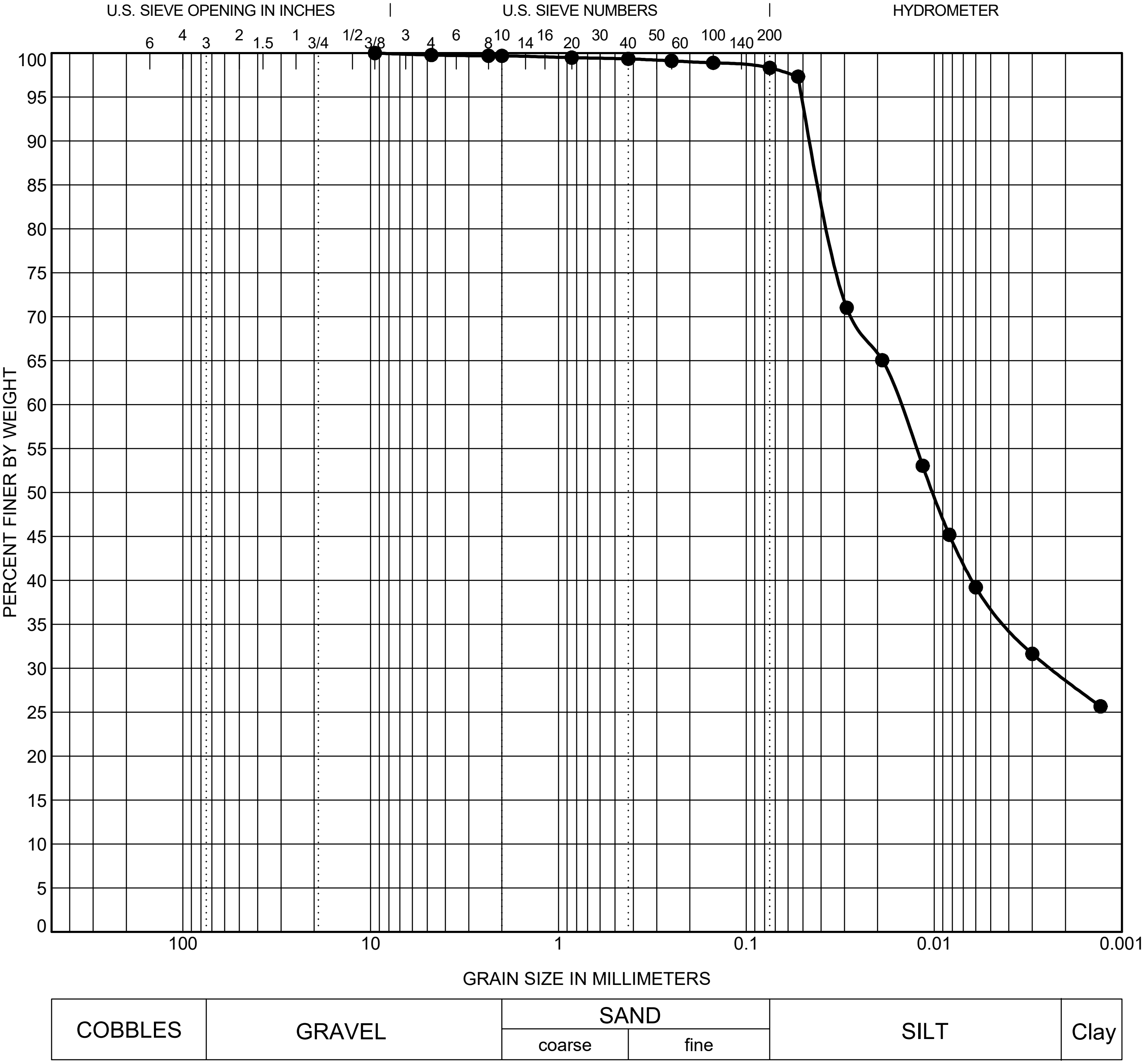
Summary of Classification Tests

DES # : N/A
County : Monroe
Route # : 17th Street
Project # : 170GC00756
Project Type : Intersection Improvements
Location : 17th Street and Dunn St. & 17th Street and Kinser Pike



	Specimen Identification			Lab #	Textural Classification	LL	PL	PI	Cc	Cu
●	**B-101**	**SS1**	**1.0**	**1**	**A-7-6 (32) SILTY CLAY LOAM**	**47**	**16**	**31**		

	Specimen Identification			D60	D30	D10	LOI	Ca/Mg	%Gravel	%Sand	%Silt	%Clay	%Colloid
●	**B-101**	**SS1**	**1.0**	**0.015**	**0.002**				**0.3**	**1.4**	**69.6**	**28.7**	

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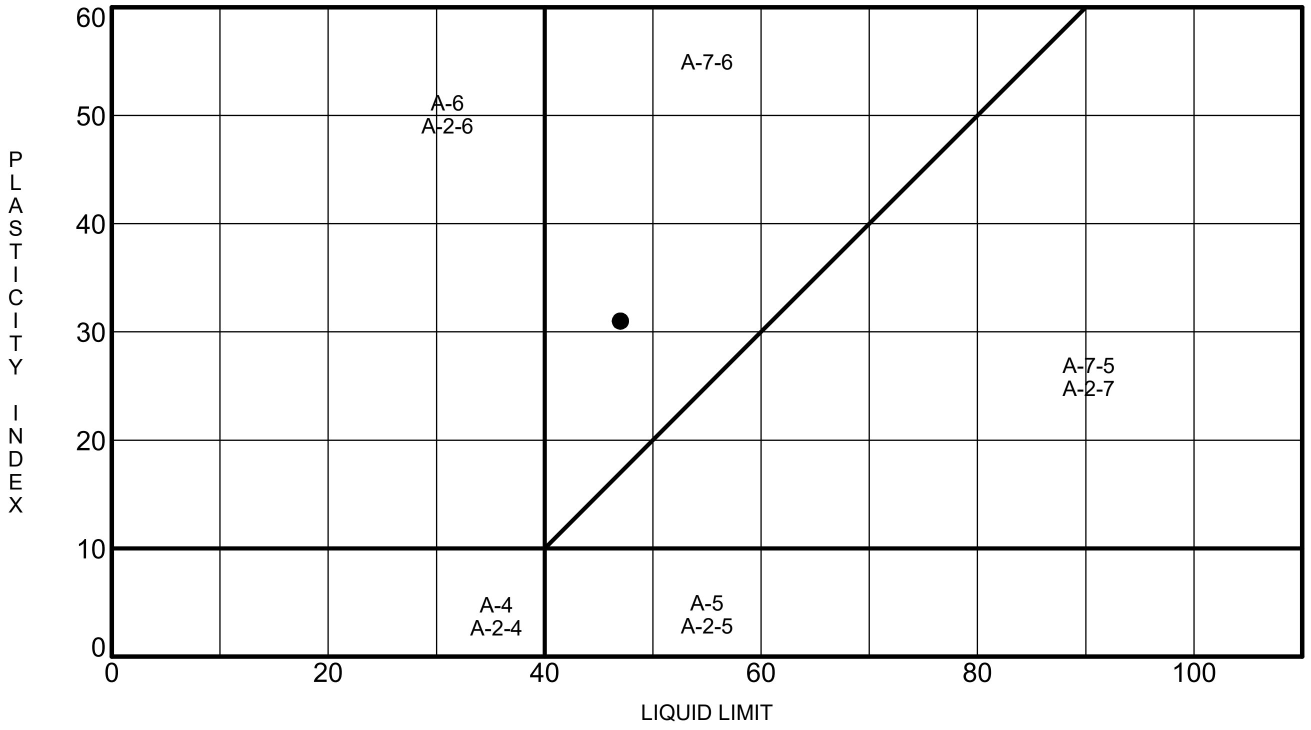
GRAIN SIZE DISTRIBUTION TEST REPORT

DES #: N/A Structure #: Kinser Pike
Project #: 170GC00756
County: Monroe
Location: 17th Street at Kinser Pike, Bloomington, Ind.



	Specimen Identification		LL	PL	PI	Fines	Classification
●	**B-101**	**1.00**	**47**	**16**	**31**	**98**	**A-7-6 (32) SILTY CLAY LOAM**

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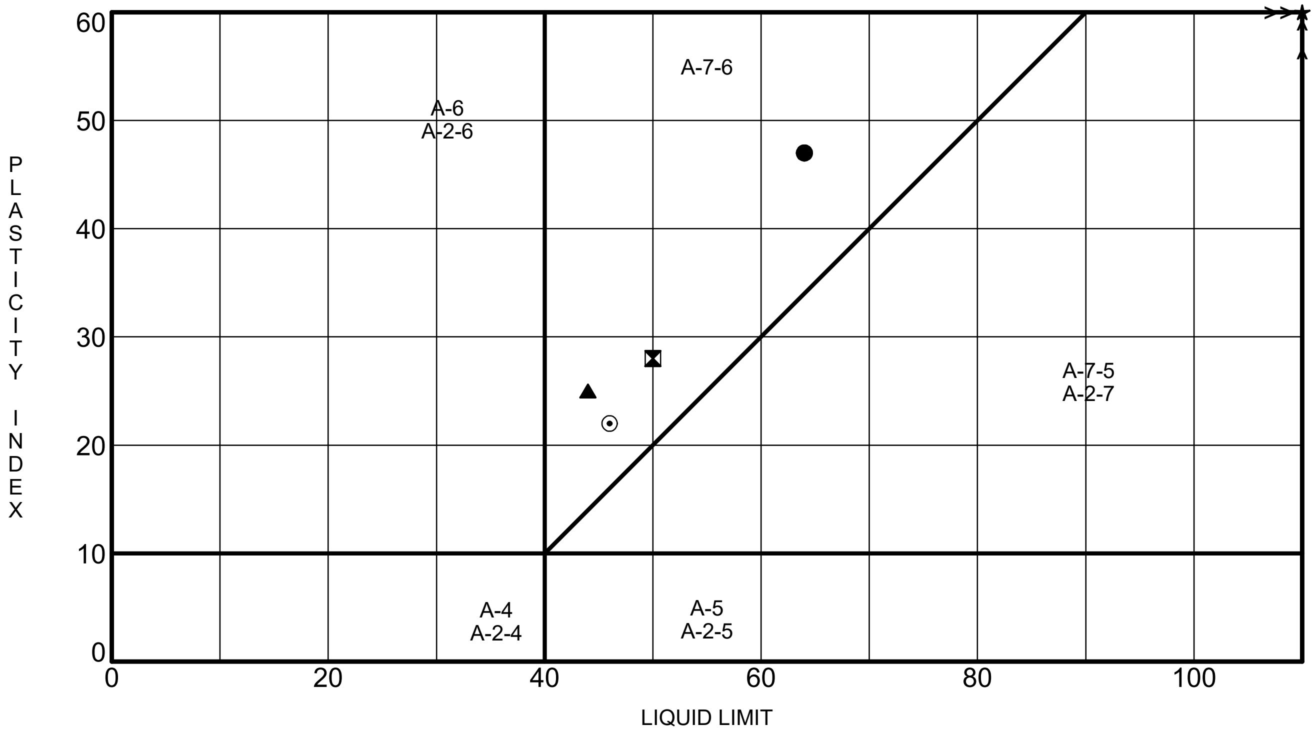
ATTERBERG LIMITS' RESULTS

DES #: N/A Structure #: Kinser Pike
Project #: 170GC00756
County: Monroe
Location: 17th Street at Kinser Pike, Bloomington, Ind.



	Specimen Identification		LL	PL	PI	Fines	Classification
●	**B-1**	**3.50**	**64**	**17**	**47**		**A-7-6**
⧗	**B-2**	**3.50**	**50**	**22**	**28**		**A-7-6**
▲	**RB-1**	**4.00**	**44**	**19**	**25**		**A-7-6**
★	**RB-1**	**11.00**	**141**	**28**	**113**		**A-7-5**
⊙	**RW-2**	**3.50**	**46**	**24**	**22**		**A-7-6**

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ATTERBERG LIMITS' RESULTS

DES #: N/A Structure #: Dunn Street
Project #: 170GC00756
County: Monroe
Location: 17th Street at Dunn St., Bloomington, Ind.

Boring	Sample	Depth	Specific Gravity	Dry Density (pcf)	Qu (tsf)	c (tsf)	ϕ (deg)	Moisture %	Max Dry Density (pcf)	Opt. Moisture %	Resilient Modulus (MR)		Void Ratio	Collapse Index	LOI (%)	Ca/Mg CO3 (%)
											MR @ Optimum	MR @ In Situ Condition				
B-1	SS1	1 - 2.5						23.3								
B-1	SS2	3.5 - 5						24.8								
B-1	SS3	6 - 7.5														
B-101	SS1	1 - 2.5	2.712					29.6								
B-101	SS2	3.5 - 5						27.6								
B-102	SS1	1 - 2.5						25.6								
B-102	SS2	3.5 - 5						27.4								
B-102	SS3	6 - 7.5						26.7								
B-2	SS1	1 - 2.5						25.4								
B-2	SS2	3.5 - 5						26.7								
B-2	SS3	6 - 7.5						34.2								
B-2	SS4	8.5 - 10						40.9								
RB-1	SS1	1 - 2.5						27.2								
RB-1	SS2	2.5 - 4						26.6								
RB-1	SS3	4 - 5.5						24.8								
RB-1	SS4	6 - 7.5						27.1								
RB-1	SS5	8.5 - 10						38.2								
RB-1	SS6	11 - 12.5						68.3							6.9	6
RB-2	SS1	0.5 - 1.5						18.6								
RB-2	SS2	1.5 - 3						22.7								
RB-2	SS3	3 - 4.5						27.2								
RB-2	SS4	6 - 7.5						28.4								
RW-1	SS1	1 - 2.5						28.6								
RW-1	SS2	3.5 - 5						24.9								
RW-1	SS3	6 - 7.5						54.6								
RW-1	SS4	8.5 - 10						41.8								
RW-1	SS5	11 - 12.5						51.6								
RW-2	SS1	1 - 2.5						26.0								

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Summary of Special Lab Tests

DES # : N/A
County : Monroe
Route # : 17th Street
Project # : 170GC00756
Project Type : Intersection Improvements
Location : 17th Street and Dunn St. & 17th Street and Kinser Pike

Boring	Sample	Depth	Specific Gravity	Dry Density (pcf)	Qu (tsf)	c (tsf)	ϕ (deg)	Moisture %	Max Dry Density (pcf)	Opt. Moisture %	Resilient Modulus (MR)		Void Ratio	Collapse Index	LOI (%)	Ca/Mg CO3 (%)
											MR @ Optimum	MR @ In Situ Condition				
RW-2	SS2	3.5 - 5						34.6								
RW-2	SS3	6 - 7.5						24.5								
RW-2	SS4	8.5 - 10						39.4								

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Summary of Special Lab Tests

DES # : N/A
County : Monroe
Route # : 17th Street
Project # : 170GC00756
Project Type : Intersection Improvements
Location : 17th Street and Dunn St. & 17th Street and Kinser Pike

APPENDIX D

AASHTO SEISMIC PARAMETERS

17th Street Intersection Improvements

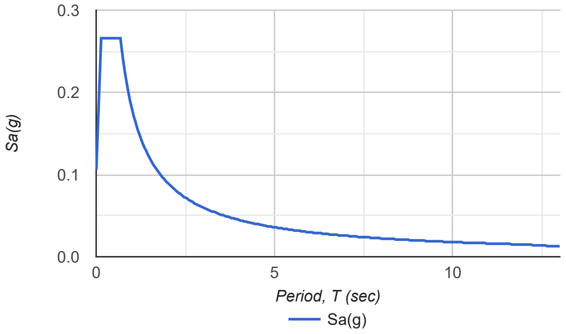
Latitude, Longitude: 39.17853070, -86.52832159

Date	5/1/2019, 9:24:27 AM
Design Code Reference Document	ASCE7-10
Risk Category	II
Site Class	C - Very Dense Soil and Soft Rock

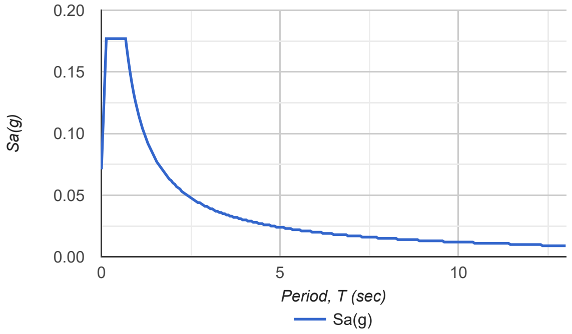
Type	Value	Description
S_S	0.222	MCE$_R$ ground motion. (for 0.2 second period)
S_1	0.106	MCE$_R$ ground motion. (for 1.0s period)
S_{MS}	0.266	Site-modified spectral acceleration value
S_{M1}	0.18	Site-modified spectral acceleration value
S_{DS}	0.177	Numeric seismic design value at 0.2 second SA
S_{D1}	0.12	Numeric seismic design value at 1.0 second SA

Type	Value	Description
SDC	B	Seismic design category
F_a	1.2	Site amplification factor at 0.2 second
F_v	1.694	Site amplification factor at 1.0 second
PGA	0.106	MCE$_G$ peak ground acceleration
F_{PGA}	1.2	Site amplification factor at PGA
PGA_M	0.127	Site modified peak ground acceleration
T_L	12	Long-period transition period in seconds
SsRT	0.222	Probabilistic risk-targeted ground motion. (0.2 second)
SsUH	0.246	Factored uniform-hazard (2% probability of exceedance in 50 years) spectral acceleration
SsD	1.5	Factored deterministic acceleration value. (0.2 second)
S1RT	0.106	Probabilistic risk-targeted ground motion. (1.0 second)
S1UH	0.124	Factored uniform-hazard (2% probability of exceedance in 50 years) spectral acceleration.
S1D	0.6	Factored deterministic acceleration value. (1.0 second)
PGAd	0.5	Factored deterministic acceleration value. (Peak Ground Acceleration)
C_{RS}	0.899	Mapped value of the risk coefficient at short periods
C_{R1}	0.854	Mapped value of the risk coefficient at a period of 1 s

MCER Response Spectrum



Design Response Spectrum



DISCLAIMER

APPENDIX E

RETAINING WALL ANALYSIS

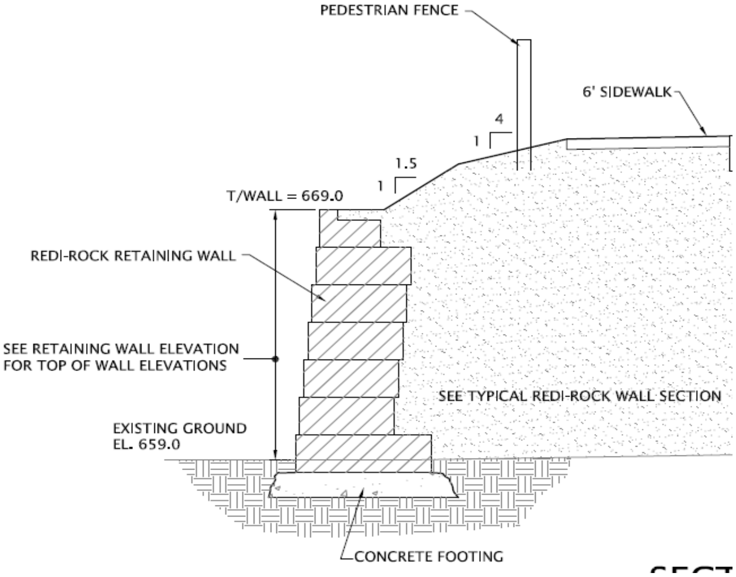
Retaining Wall Analysis - Prefabricated Modular Walls

Per AASHTO with 2017 Interim Editions

Project: Intersection Improvement at 17th Street with North Dunn Street
Location: Bloomington, IN
DES No.: N/A Job # 170GC00756
Soil Boring : RW-1
Scope : Retaining Wall External Analysis
Analyzed by : EAW

Geometry :

Gravity Wall at Sta. 25+50, 34ft. Lt.



Top of Wall Elevation: 813 ft

Top of soil in front of wall 807.5 ft

Bottom of Wall Elevation 805 ft
Leveling Pad Elevation:* 805 ft

**Bottom of foundation must be a minimum of 36" beneath finished grade for frost protection.*

Length of Wall 180 feet 125

**Maximum Wall Height is taken as the distance from the leveling pad to the top of proposed profile grade*

q (traffic surcharge) = 250 psf
H (Max Wall Height) = 8 feet

Soil Properties

	Backfill	Retained	Foundation Soil	
Cohesion (c) =	0	0	1000	psf
Angle of Internal Friction (ϕ)=	34	28	0	
Unit Weight (γ) =	120	120	120	pcf

Foundation Soils: Silty Clay Loam, A-7-6

Per IDM 410-5, the soil below the leveling pad which is subject to frost heave should be removed to an elevation 3 ft below finished grade and replaced with granular backfill

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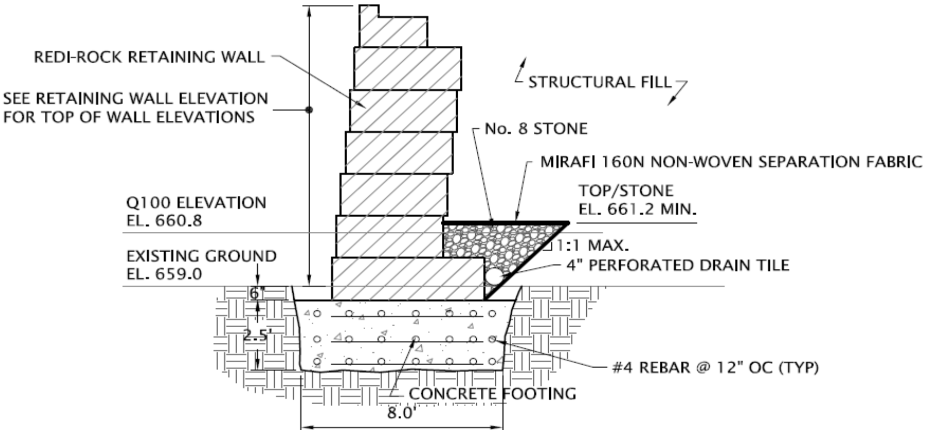
Retaining Wall Analysis - Prefabricated Modular Walls

Per AASHTO with 2017 Interim Editions

Project: Intersection Improvement at 17th Street with North Dunn Street
Location: Bloomington, IN
DES No.: N/A Job # 170GC00756
Soil Boring : RW-1
Scope : Retaining Wall External Analysis
Analyzed by : EAW

Step 1: Calculate the unfactored vertical loads

(A) Dead Load of Structural Components (DC) *(base width is typically 0.5H to 0.7H)*



*If concrete footing to be utilized, assume a unit weight of concrete, γ_c *(pcf)* 120

Wall Height, H =	8	ft	*H:W Ratio*	0.7	
Foundation Height =	0	ft	*Minimum Base Width, B =*	8	ft
Block Height, H_1 =	1.5	ft	*Block Width, B_1 =*	2.3	ft
Block Height, H_2 =	1.5	ft	*Block Width, B_2 =*	3.4	ft
Block Height, H_3 =	1.5	ft	*Block Width, B_3 =*	5.0	ft

Block Quantity:

Type 1	1	W_1 =	$B_1 H_1 \gamma_c$ =	416.25	lbs/ft
Type 2	4	W_2 =	$B_2 H_2 \gamma_c$ =	607.5	lbs/ft
Type 3	1	W_3 =	$B_3 H_3 \gamma_c$ =	900	lbs/ft
		W_B =	$W_1 + W_2 + W_3$ =	1923.75	lbs/ft
Height Check:	9	*Wf* =	$BFH \gamma_c$ =	0	lbs/ft

(B) Vertical Earth Pressure (EV) & Live Load Surcharge (LS)

Block Set Back =	1.62	in
Bottom Block Set Back =	1.62	ft
Top of Wall Set Back =	2.43	ft
Soil Width, Bs=	5.3	ft

Retaining Wall Analysis - Prefabricated Modular Walls

Per AASHTO with 2017 Interim Editions

Project: Intersection Improvement at 17th Street with North Dunn Street
Location: Bloomington, IN
DES No.: N/A Job # 170GC00756
Soil Boring : RW-1
Scope : Retaining Wall External Analysis
Analyzed by : EAW

Definitions:

Vertical Earth Pressure (P_{EV}) = W_4 = $B_s H \gamma_b$ = 5100.2 lbs/ft

Live Load Surcharge(P_{LSV}) = qB_3 = *1250* lbs/ft wall length

Footing Width *(B)* =	8 ft
Adhesion ($C_{a)}$ =	700 psf

	V (kips/ft)	Moment Arm About Toe (ft)	Moment About Toe (kip-ft/ft)
W_B	1.92	1.53	2.95
W_f	0.00	4.00	0.00
P_{EV}	5.10	5.50	28.05
P_{LSV}	1.25	5.50	6.88
Total	**8.27**		

Step 2: Calculate the unfactored horizontal loads

Definitions:

active earth pressure coefficient (k_a) = $\tan^2(45-\phi/2)$ = 0.36

Change in Horizontal Pressure due to Live Load (ΔP) = $k_a q$ = 90.3 psf

Live Load Horizontal Earth Pressure (P_{LSH}) = ΔPH 722.1 lbs/ft

Horizontal Earth Pressure (P_{EH}) = $1/2\gamma_b H^2 k_a$ 1386.4 lbs/ft

Unit Weight of retained soil (γ_b)

	H (kip/ft)	Moment Arm About Toe (ft)	Moment About Toe (kip-ft/ft)
P_{LSH}	0.72	4.00	2.89
P_{EH}	1.39	2.67	3.70
Total	2.11		

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Retaining Wall Analysis - Prefabricated Modular Walls

Per AASHTO with 2017 Interim Editions

Project: Intersection Improvement at 17th Street with North Dunn Street
Location: Bloomington, IN
DES No.: N/A Job # 170GC00756
Soil Boring : RW-1
Scope : Retaining Wall External Analysis
Analyzed by : EAW

Step 3: Determine the appropriate load factors (γ_p) using Table 3.4.1-2

Group	$\gamma_{p(DC)}$	$\gamma_{p(EV)}$	$\gamma_{p(EH)}$ (Active)	$\gamma_{p(LS)}$	Use
Strength I-a (min.)	0.90	1.00	1.50	1.75	BC/EC/SL
Strength I-b(max.)	1.25	1.35	1.50	1.75	BC(max)
Service I	1.00	1.00	1.00	1.00	Settlement

Note: BC- Bearing Capacity; EC- Eccentricity; SL- Sliding

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Retaining Wall Analysis - Prefabricated Modular Walls

Per AASHTO with 2017 Interim Editions

Project: Intersection Improvement at 17th Street with North Dunn Street
Location: Bloomington, IN
DES No.: N/A Job # 170GC00756
Soil Boring : RW-1
Scope : Retaining Wall External Analysis
Analyzed by : EAW

Step 4: Determine the factored loads and factored moments

Factored Vertical Loads

Group/Item	W_1 (Kips/ft)	W_3 (Kips/ft)	P_{EV} (Kips/ft)	P_{LSV} (Kips/ft)	Total (Kips/ft)
V (Unf.)	1.92	0.00	5.10	1.25	8.27
Strength I-a	1.73	0.00	5.10	2.19	9.02
Strength I-b	2.40	0.00	6.89	2.19	11.48
Service I	1.92	0.00	5.10	1.25	8.27

Factored Horizontal Loads

Group/Item	P_{LSH} (Kips/ft)	P_{EH} (Kips/ft)	Total (Kips/ft)
H (Unf.)	0.72	1.39	2.11
Strength I-a	1.26	2.08	3.34
Strength I-b	1.26	2.08	3.34
Service I	0.72	1.39	2.11

Factored Moments from Vertical Forces (Mv)

Group/Item	W_1 (Kips/ft)	W_3 (Kips/ft)	P_{EV} (Kips-ft/ft)	P_{LSV} (Kip-ft/ft)	Total (Kip-ft/ft)
Mv (Unf.)	2.95	0.00	28.05	6.88	37.87
Strength I-a	2.65	0.00	28.05	12.03	42.73
Strength I-b	3.68	0.00	37.87	12.03	53.58
Service I	2.95	0.00	28.05	6.88	37.87

Factored Moments from Horizontal Forces (Mh)

Group/Item	P_{LSH} (Kips-ft/ft)	P_{EH} (Kip-ft/ft)	Total (Kip-ft/ft)
Mh (Unf.)	2.89	3.70	6.59
Strength I-a	5.05	5.55	10.60
Strength I-b	5.05	5.55	10.60
Service I	2.89	3.70	6.59

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Retaining Wall Analysis - Prefabricated Modular Walls

Per AASHTO with 2017 Interim Editions

Project: Intersection Improvement at 17th Street with North Dunn Street
Location: Bloomington, IN
DES No.: N/A Job # 170GC00756
Soil Boring : RW-1
Scope : Retaining Wall External Analysis
Analyzed by : EAW

Step 5: Determine Factor of Safety for Overturning and Check Eccentricity

Definitions:

Factored Vertical Dead Load ($V_{Dead\ Load}$)= $P_{EV}\gamma_{p(LS)}$

Factored Horizontal Load (H_{total}) = $P_{LSH}+P_{EH}$

Factored Moment about Toe (vertical)= $M_{V.Dead\ Load}$

Factored Moment about Toe (horizontal) = M_{Htotal}

Location of the Resultant from the Toe of Wall (x_o) = $(M_{v.Dead\ Load}) - M_{htotal})/V_{Dead\ Load}$

Eccentricity (e) = B/2 - Xo

B/2 = 4.00 ft

*e_{max} = B/4 = 2.00 ft

*the location of the resultant must be in the middle half of the base. For all cases, e<e_{max}; in order for the design to be adequate.

Group/Item	$V_{Dead\ Load}$ (Kip/ft)	H_{total} (Kip/ft)	$M_{V.Dead\ Load}$ (Kip-ft/ft)	M_{htotal} (Kip-ft/ft)	Xo (ft)	e (ft)
Strength I-a	6.83	3.34	30.70	10.60	2.94	1.06
Strength I-b	9.29	3.34	41.55	10.60	3.33	0.67
Service I	7.02	2.11	31.00	6.59	3.48	0.52

Check Eccentricity

Strength I-a	e	< emax	OK
Strength I-b	e	< emax	OK
Service I	e	< emax	OK

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Retaining Wall Analysis - Prefabricated Modular Walls

Per AASHTO with 2017 Interim Editions

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Location: Bloomington, IN
DES No.: N/A Job # 170GC00756
Soil Boring : RW-1
Scope : Retaining Wall External Analysis
Analyzed by : EAW

Step 6: Determine Factor of Safety against Bearing Capacity Failure

Definitions:

N_γ, N_q, N_c Bearing capacity factors (Table 10.6.3.1.2a-1)
φ_b resistance factor (Table 10.5.5.2.2-1)
σ_v Vertical stress

$$\sigma_v = \frac{\sum V}{B-2e}$$

S_c, S_γ, S_q Shape Correction Factors (Table 10.6.3.1.2a-3)
C_{wq} and C_{wg} coefficients for groundwater depths (Table 10.6.3.1.2a-2)
Nominal Bearing Resistance (q_n) = $cN_cS_ci_c+\gamma D_fN_qS_qd_qi_qC_{wq}+0.5\gamma B'N_\gamma S_\gamma i_\gamma C_{w\gamma}$
Factored Unit Bearing Resistance (q_R) = φ_bq_n
reduced footing width due to eccentricity (B') = B-2e

N_γ = 0
N_q = 1
N_c = 5.14
ϕ = 0
φ_b 0.50 *Table 11.5.6-1, AASHTO*

Min B of footing = 8.00 feet B/2= 4 ft
Min D_f of footing = 36 inches
e_{max} = B/4 = 2.00 ft
S_c= 1+(B/L)(Nq/Nc) 1.0 No Inclination so i_c, i_q, i_γ = 1
S_γ= 1-0.4(B/L) 1.0
S_q= 1+(B/L)tanϕf 1.0

GW greater than 5 feet so C_{wq} and $C_{w\gamma}$ = 1

C_{wq} = 1 $C_{w\gamma}$ = 1

Group/Item	$V_{total.}$ (Kip/ft)	H_{total} (Kip/ft)	M_{Vtotal} (Kip-ft/ft)	M_{Htotal} (Kip-ft/ft)	X_o (ft)	e2 (ft)
Strength I-a	9.02	3.34	42.73	10.60	3.56	0.44
Strength I-b	11.48	3.34	53.58	10.60	3.74	0.26
Service I	8.27	2.11	37.87	6.59	3.78	0.22

Group/Item	B' (ft)	q_N (psf)	q_R (psf)	σv (psf/ft)	CDR	CDR>1
Strength I-a	7.13	5544.44	2772.22	1265.72	2.2	OK
Strength I-b	7.49	5544.44	2772.22	1532.40	1.8	OK
Service I	7.56	5544.44	2772.22	1094.06	2.5	OK

Retaining Wall Analysis - Prefabricated Modular Walls

Per AASHTO with 2017 Interim Editions

Project: Intersection Improvement at 17th Street with North Dunn Street
Location: Bloomington, IN
DES No.: N/A Job # 170GC00756
Soil Boring : RW-1
Scope : Retaining Wall External Analysis
Analyzed by : EAW

Step 7: Determine Factor of Safety against Sliding

Normal Shear Resistance (R_{τ}) = ϕ_{τ}*V*Tan δ *(cohesionless soils) Eqn. 10.6.3.4-2*

Normal Shear Resistance (R_{τ}) = ϕ_{τ}*V*Tan δ + c_a *(clay soils)*

resistance factor (φ_{τ}) =	1	*Table 11.5.6-1*	
δ =	22	degrees	*NAVFAC 7.2*
V =0.9*DC+P_{EV} =	6.83	kips/ft	*(Total Vertical Force)*
$\varphi_t R_{\tau}$ =	3.46	kips/ft length of wall	
H_{total} =	3.34	kips/ft	Factored Horizontal Load

Check Sliding	R_{τ}	>	H_{total}	OK	per LRFD

Therefore, the wall is **STABLE** based upon the above stability analysis per LRFD.

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Retaining Wall Analysis - Prefabricated Modular Walls

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DES No.: N/A Job # 170GC00756
Soil Boring : RW-1
Scope : Retaining Wall External Analysis
Analyzed by : EAW

Step 8: Determine Preliminary Factor of Safety for Global Stability

echnical Manual, Sec. 6.3.3.

Rules of thumb that can be used to make a preliminary assessment of the Factor of Safety (FOS) to prevent failure.

One such rule is: (Taylor's equation)

$$\mathrm{FOS} = \frac{6C}{\gamma H}$$

where:

C = cohesion of soft foundation foil

γ = unit weight of embankment soil

H = Height of slope

The FOS computed using the above equation should not be used for final design. This simple equation can be used to preliminarily check both slope and foundation (base) stability. If the factor of safety is less than 2.5, a more sophisticated stability analysis is required.

Preliminary FOS = **6.25** > 2.5

Ok for preliminary design. Must be reevaluated for final design when plans are available

Action Item: Perform Settlement Estimate under bearing pressure computed at a Service I limit State.

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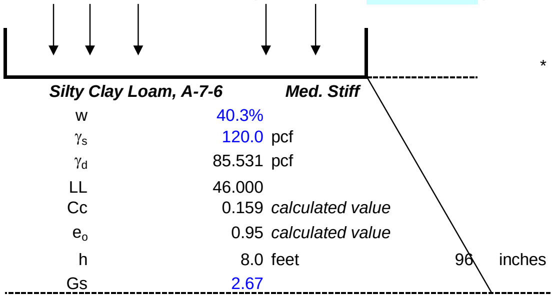
Retaining Wall Analysis - Settlement Check

Per AASHTO with 2017 Interim Editions

Project: Intersection Improvement at 17th Street with North Dunn Street
Soil Boring : RW-1
Scope : Wall Settlement Determination
Analyzed by : EAW

All parameters calculated based upon boring specific unit weight and moistures content tests. Specific gravity testing and Atterberg Limit testing was performed on parent soil type.

q_o (bearing pressure under Service I limit state) = 2772 psf



Ground Surface Elev.:	807.5				
Btm. Leveling pad Elev	805.0 ft	***Silty Clay Loam, A-7-6***		***Med. Stiff***	
Btm Foundation zone.	802.0	w	40.3%		
		γ_s	120.0	pcf	
		γ_d	85.531	pcf	
		LL	46.000		
		Cc	0.159	*calculated value*	
		e_o	0.95	*calculated value*	
		h	8.0	feet	96 inches
Depth:	13.5	Gs	2.67		
Elev.:	794.0 ft	***Rock***			

Definitions:

w moisture content
g_d dry unit weight of soil
LL Liquid Limit
Cc Compression Index*
* *Calculated by correlation, INDOT GSS Manual Table 6.1*
Cc = 0.156eo+0.0107
All Clays

Cr Recompression Index

e_o initial void ratio**
***Calculated using void ratio relationship*

$$e_o = \frac{G_s \gamma_w}{\gamma_d} - 1$$

h Height of layer
G_s Specific Gravity
γ_s unit weight of soil

Step 1: Calculate all stresses

Water Depth	12.8	
Soil Layer		1
Depth	12.8	13.5
Unit Weight	120.0	120.0
Pore Water Pressure	0	43.68
Pore Water Pressure at Midpoint	0	21.84
Total Stress at Midpoint	768	1578
Total Stress for Layer	1536	1620
Effective Vertical Stress at Midpoint	768	1556.16
Effective Vertical Stress for Layer	1536	1576.32

Water Table: 12.8 ft

GW Elev.: 792.2 ft

Step 2: Calculate the increase of vertical pressure for compressible layers (***Δp)***

Footing Size	B=	8	feet
	L=	180	feet
		1440	ft^2
Load on footing =		2772.2	psf
		3992000.0	pounds

Use a 1(H):2(V) pressure distribution

Layer 1 **Δp_1** 2268.72 psf at center of layer

Step 3: Calculate Settlement of the first compressible layer

p_{o1} 1556 psf is present at midpoint of **Silty Clay Loam, A-7-6**

$$S_C = \frac{C_c H}{1+e_o} * \log\left(\frac{p_o + \Delta p}{p_0}\right)$$

S_1 3.1 inches
0.08 m

within the **Silty Clay Loam, A-7-6**

Step 4: Determine total estimated settlement **(S_T)** of system

S_T 3.1 inches***
0.08 m

****Per INDOT GSS Manual 6.1*

For very soft to soft clays (Qu between 0.25 to 0.50 tsf), the settlements computed by this method are likely to be reasonably accurate. For medium and stiff clays (Qu between 0.5 and 2.0 tsf), the actual settlements are likely to range between one-fourth and one-tenth of the computed values.

*Influence values determined using chart (Table 8.5) provided in Holtz & Kovaks (1981)

For medium stiff tostiff clays, the actual settlement is expected to range from one-fourth to one-tenth of the computed value. No additional Analysis needed.

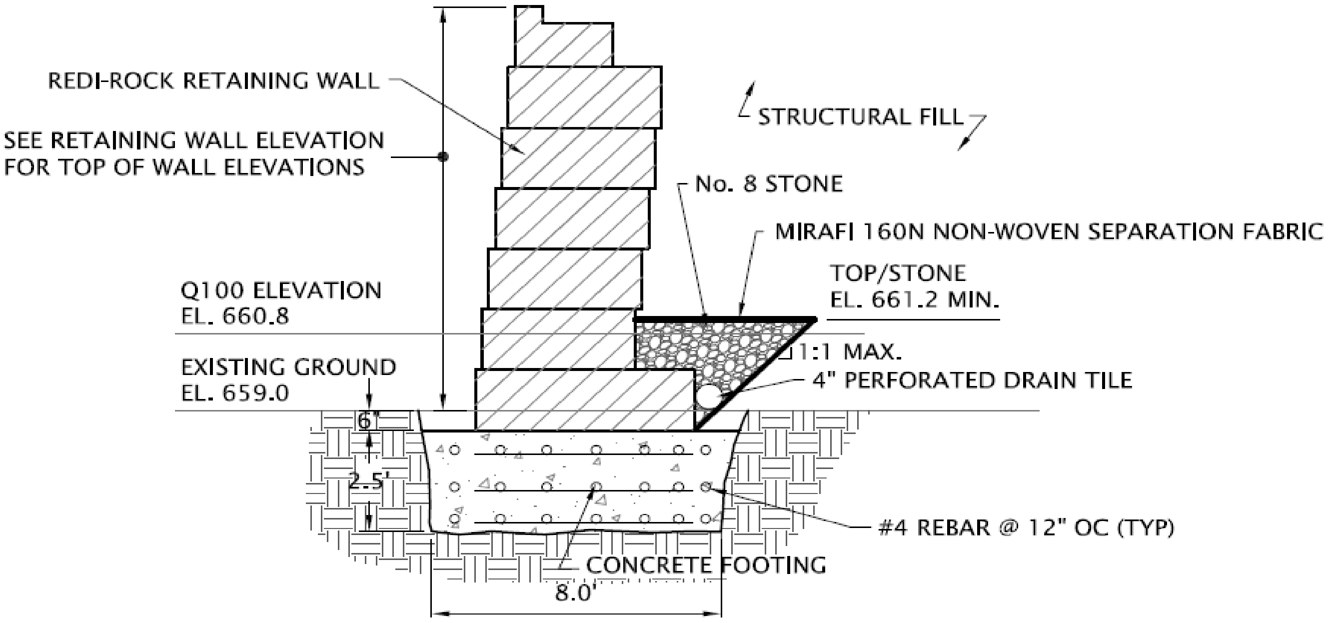
Retaining Wall Analysis - Prefabricated Modular Walls

Per AASHTO with 2017 Interim Editions

Project: Intersection Improvement at 17th Street with North Dunn Street
Location: Bloomington, IN
DES No.: N/A Job # 170GC00756
Soil Boring : RW-1
Scope : Retaining Wall External Analysis
Analyzed by : EAW

Design Recommendations:

Required Minimum Base Width to Wall Height Ratio= **0.7** or a minimum base width of 8 ft



Total Wall Height, H =	9	ft	*Minimum Base Width, B =*	8	ft
Foundation Height =	0	ft	Block Set Back =	1.62	in
All Block Heights =	1.5	ft	Bottom Block Set Back =	1.62	ft

<u>Block Quantity:</u>

Type 1	1	@	27.8	in
Type 2	4	@	40.5	in
Type 3	1	@	60.0	in

Nominal Bearing Resistance (q_n) = *5544* *psf*

φ_b resistance factor (Table 10.5.5.2.2-1) *0.50*

Recommended Factored Unit Bearing Resistance (q_R) = ***2800*** ***psf***

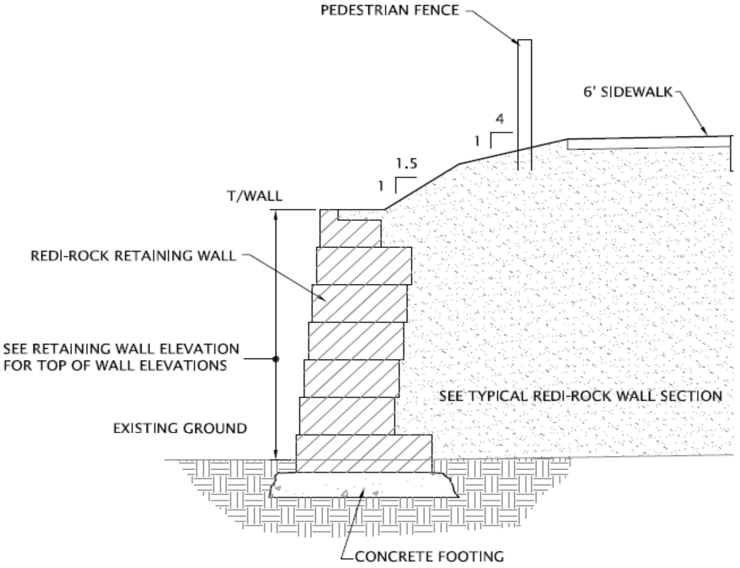
Retaining Wall Analysis - Prefabricated Modular Walls

Per AASHTO with 2017 Interim Editions

Project: Intersection Improvement at 17th Street with North Dunn Street
Location: Bloomington, IN
DES No.: N/A Job # 170GC00756
Soil Boring : RW-2
Scope : Retaining Wall External Analysis
Analyzed by : EAW

Geometry :

Gravity Wall at Sta. 26+25, 20ft. Rt.



Top of Wall Elevation: 814.5 ft

Top of soil in front of wall 809.5 ft

Bottom of Wall Elevation 807.5 ft
Leveling Pad Elevation:* 807.5 ft

**Bottom of foundation must be a minimum of 36" beneath finished grade for frost protection.*

Approx. Length of Wall 135 feet

**Maximum Wall Height is taken as the distance from the leveling pad to the top of proposed profile grade*

q (traffic surcharge) = 250 psf
H (Max Wall Height) = 7 feet

Soil Properties

	Backfill	Retained	Foundation Soil	
Cohesion (c) =	0	0	1000	psf
Angle of Internal Friction (ϕ)=	34	28	0	
Unit Weight (γ) =	120	120	120	pcf

Foundation Soils: Silty Clay Loam, A-7-6

Per IDM 410-5, the soil below the leveling pad which is subject to frost heave should be removed to an elevation 3 ft below finished grade and replaced with granular backfill

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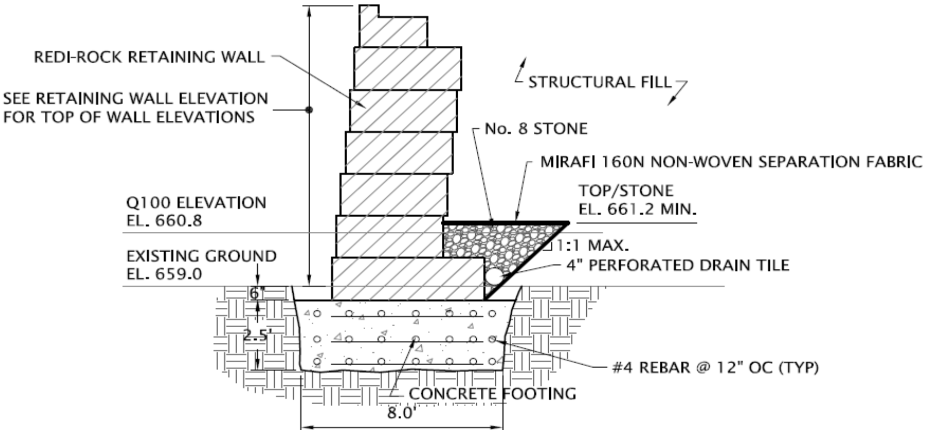
Retaining Wall Analysis - Prefabricated Modular Walls

Per AASHTO with 2017 Interim Editions

Project: Intersection Improvement at 17th Street with North Dunn Street
Location: Bloomington, IN
DES No.: N/A Job # 170GC00756
Soil Boring : RW-2
Scope : Retaining Wall External Analysis
Analyzed by : EAW

Step 1: Calculate the unfactored vertical loads

(A) Dead Load of Structural Components (DC) *(base width is typically 0.5H to 0.7H)*



*If concrete footing to be utilized, assume a unit weight of concrete, γ_c *(pcf)* 120

Wall Height, H =	7	ft	*H:W Ratio*	0.7	
Foundation Height =	0	ft	*Minimum Base Width, B =*	8	ft
Block Height, H_1 =	1.5	ft	*Block Width, B_1 =*	2.3	ft
Block Height, H_2 =	1.5	ft	*Block Width, B_2 =*	3.4	ft
Block Height, H_3 =	1.5	ft	*Block Width, B_3 =*	5.0	ft

Block Quantity:

Type 1	1	W_1 =	$B_1 H_1 \gamma_c$ =	416.25	lbs/ft
Type 2	4	W_2 =	$B_2 H_2 \gamma_c$ =	607.5	lbs/ft
Type 3	1	W_3 =	$B_3 H_3 \gamma_c$ =	900	lbs/ft
		W_B =	$W_1 + W_2 + W_3$ =	1923.75	lbs/ft
Height Check:	9	*Wf* =	$BFH \gamma_c$ =	0	lbs/ft

(B) Vertical Earth Pressure (EV) & Live Load Surcharge (LS)

Block Set Back = 1.62 in
Bottom Block Set Back = 1.62 ft
Top of Wall Set Back = 2.43 ft
Soil Width, Bs= 4.8 ft

Retaining Wall Analysis - Prefabricated Modular Walls

Per AASHTO with 2017 Interim Editions

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Soil Boring : RW-2
Scope : Retaining Wall External Analysis
Analyzed by : EAW

Definitions:

Vertical Earth Pressure (P_{EV}) = W_4 = $B_s H \gamma_b$ = 3994.4 lbs/ft
Live Load Surcharge(P_{LSV}) = qB_3 = *1250* lbs/ft wall length

Footing Width *(B)* =	8	ft
Adhesion ($C_{a)}$ =	700	psf

	V (kips/ft)	**Moment Arm About Toe (ft)**	**Moment About Toe (kip-ft/ft)**
W_B	1.92	2.09	4.02
W_f	0.00	4.00	0.00
P_{EV}	3.99	5.50	21.97
P_{LSV}	1.25	5.50	6.88
Total	**7.17**		

Step 2: Calculate the unfactored horizontal loads

Definitions:

active earth pressure coefficient (k_a) = $\tan^2(45-\phi/2)$ = 0.36
Change in Horizontal Pressure due to Live Load (ΔP) = $k_a q$ = 90.3 psf
Live Load Horizontal Earth Pressure (P_{LSH}) = ΔPH 631.8 lbs/ft
Horizontal Earth Pressure (P_{EH}) = $1/2\gamma_b H^2 k_a$ 1061.4 lbs/ft
Unit Weight of retained soil (γ_b)

	H (kip/ft)	**Moment Arm About Toe (ft)**	**Moment About Toe (kip-ft/ft)**
P_{LSH}	0.63	3.50	2.21
P_{EH}	1.06	2.33	2.48
Total	1.69		

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Retaining Wall Analysis - Prefabricated Modular Walls

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Step 3: Determine the appropriate load factors (γ_p) using Table 3.4.1-2

Group	$\gamma_{p(DC)}$	$\gamma_{p(EV)}$	$\gamma_{p(EH)}$ (Active)	$\gamma_{p(LS)}$	Use
Strength I-a (min.)	0.90	1.00	1.50	1.75	BC/EC/SL
Strength I-b(max.)	1.25	1.35	1.50	1.75	BC(max)
Service I	1.00	1.00	1.00	1.00	Settlement

Note: BC- Bearing Capacity; EC- Eccentricity; SL- Sliding

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Retaining Wall Analysis - Prefabricated Modular Walls

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Step 4: Determine the factored loads and factored moments

Factored Vertical Loads

Group/Item	W_1 (Kips/ft)	W_3 (Kips/ft)	P_{EV} (Kips/ft)	P_{LSV} (Kips/ft)	Total (Kips/ft)
V (Unf.)	1.92	0.00	3.99	1.25	7.17
Strength I-a	1.73	0.00	3.99	2.19	7.91
Strength I-b	2.40	0.00	5.39	2.19	9.98
Service I	1.92	0.00	3.99	1.25	7.17

Factored Horizontal Loads

Group/Item	P_{LSH} (Kips/ft)	P_{EH} (Kips/ft)	Total (Kips/ft)
H (Unf.)	0.63	1.06	1.69
Strength I-a	1.11	1.59	2.70
Strength I-b	1.11	1.59	2.70
Service I	0.63	1.06	1.69

Factored Moments from Vertical Forces (Mv)

Group/Item	W_1 (Kips/ft)	W_3 (Kips/ft)	P_{EV} (Kips-ft/ft)	P_{LSV} (Kip-ft/ft)	Total (Kip-ft/ft)
Mv (Unf.)	4.02	0.00	21.97	6.88	32.86
Strength I-a	3.62	0.00	21.97	12.03	37.62
Strength I-b	5.02	0.00	29.66	12.03	46.71
Service I	4.02	0.00	21.97	6.88	32.86

Factored Moments from Horizontal Forces (Mh)

Group/Item	P_{LSH} (Kips-ft/ft)	P_{EH} (Kip-ft/ft)	Total (Kip-ft/ft)
Mh (Unf.)	2.21	2.48	4.69
Strength I-a	3.87	3.72	7.58
Strength I-b	3.87	3.72	7.58
Service I	2.21	2.48	4.69

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Retaining Wall Analysis - Prefabricated Modular Walls

Per AASHTO with 2017 Interim Editions

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Soil Boring : RW-2
Scope : Retaining Wall External Analysis
Analyzed by : EAW

Step 5: Determine Factor of Safety for Overturning and Check Eccentricity

Definitions:

Factored Vertical Dead Load ($V_{Dead\ Load}$)= $P_{EV}\gamma_{p(LS)}$
Factored Horizontal Load (H_{total}) = $P_{LSH}+P_{EH}$

Factored Moment about Toe (vertical)= $M_{V.Dead\ Load}$
Factored Moment about Toe (horizontal) = M_{Htotal}
Location of the Resultant from the Toe of Wall (x_o) = $(M_{v.Dead\ Load}) - M_{htotal})/V_{Dead\ Load}$
Eccentricity (e) = B/2 - Xo

B/2 = 4.00 ft
*e_{max} = B/4 = 2.00 ft

*the location of the resultant must be in the middle half of the base. For all cases, $e<e_{max}$; in order for the design to be adequate.

Group/Item	$V_{Dead\ Load}$ (Kip/ft)	H_{total} (Kip/ft)	$M_{V.Dead\ Load}$ (Kip-ft/ft)	M_{htotal} (Kip-ft/ft)	Xo (ft)	e (ft)
Strength I-a	5.73	2.70	25.59	7.58	3.14	0.86
Strength I-b	7.80	2.70	34.68	7.58	3.48	0.52
Service I	5.92	1.69	25.99	4.69	3.60	0.40

Check Eccentricity

Strength I-a	e	< emax	OK
Strength I-b	e	< emax	OK
Service I	e	< emax	OK

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Retaining Wall Analysis - Prefabricated Modular Walls

Per AASHTO with 2017 Interim Editions

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Scope : Retaining Wall External Analysis
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Step 6: Determine Factor of Safety against Bearing Capacity Failure

Definitions:

N_γ, N_q, N_c Bearing capacity factors (Table 10.6.3.1.2a-1)

φ_b resistance factor (Table 10.5.5.2.2-1)

σ_v Vertical stress

$$\sigma_v = \frac{\sum V}{B - 2e}$$

S_c, S_γ, S_q Shape Correction Factors (Table 10.6.3.1.2a-3)

C_{wq} and C_{wg} coefficients for groundwater depths (Table 10.6.3.1.2a-2)

Nominal Bearing Resistance (q_n) = $cN_cS_ci_c+\gamma D_fN_qS_qd_qi_qC_{wq}+0.5\gamma B'N_\gamma S_\gamma i_\gamma C_{w\gamma}$

Factored Unit Bearing Resistance (q_R) = $\varphi_b q_n$

reduced footing width due to eccentricity (B') = B-2e

N_γ = 0
N_q = 1
N_c = 5.14
ϕ = 0
φ_b 0.50 *Table 11.5.6-1, AASHTO*

Min B of footing = 8.00 feet B/2= 4 ft
Min D_f of footing = 36 inches
e_{max} = B/4 = 2.00 ft
S_c= 1+(B/L)(Nq/Nc) 1.0 No Inclination so i_c, i_q, i_γ = 1
S_γ= 1-0.4(B/L) 1.0
S_q= 1+(B/L)tanϕf 1.0

GW greater than 5 feet so C_{wq} and $C_{w\gamma}$ = 1

C_{wq} = 1 $C_{w\gamma}$ = 1

Group/Item	$V_{total.}$ (Kip/ft)	H_{total} (Kip/ft)	M_{Vtotal} (Kip-ft/ft)	M_{Htotal} (Kip-ft/ft)	X_o (ft)	e2 (ft)
Strength I-a	7.91	2.70	37.62	7.58	3.80	0.20
Strength I-b	9.98	2.70	46.71	7.58	3.92	0.08
Service I	7.17	1.69	32.86	4.69	3.93	0.07

Group/Item	B' (ft)	q_N (psf)	q_R (psf)	σv (psf/ft)	CDR	CDR>1
Strength I-a	7.59	5559.26	2779.63	1042.56	2.7	OK
Strength I-b	7.84	5559.26	2779.63	1273.95	2.2	OK
Service I	7.86	5559.26	2779.63	911.87	3.0	OK

Retaining Wall Analysis - Prefabricated Modular Walls

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Soil Boring : RW-2
Scope : Retaining Wall External Analysis
Analyzed by : EAW

Step 7: Determine Factor of Safety against Sliding

Normal Shear Resistance (R_{τ}) = ϕ_{τ}*V*Tan δ *(cohesionless soils) Eqn. 10.6.3.4-2*

Normal Shear Resistance (R_{τ}) = ϕ_{τ}*V*Tan δ + c_a *(clay soils)*

resistance factor (φ_{τ}) =	1	*Table 11.5.6-1*	
δ =	22	degrees	*NAVFAC 7.2*
V =0.9*DC+P_{EV} =	5.73	kips/ft	*(Total Vertical Force)*
$\varphi_t R_{\tau}$ =	3.01	kips/ft length of wall	
H_{total} =	2.70	kips/ft	Factored Horizontal Load

Check Sliding R_{τ} > H_{total} OK per LRFD

Therefore, the wall is **STABLE** based upon the above stability analysis per LRFD.

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Retaining Wall Analysis - Prefabricated Modular Walls

Per AASHTO with 2017 Interim Editions

Project: Intersection Improvement at 17th Street with North Dunn Street
Location: Bloomington, IN
DES No.: N/A Job # 170GC00756
Soil Boring : RW-2
Scope : Retaining Wall External Analysis
Analyzed by : EAW

Step 8: Determine Preliminary Factor of Safety for Global Stability

From INDOT GSS Geotechnical Manual, Sec. 6.3.3.

Rules of thumb that can be used to make a preliminary assessment of the Factor of Safety (FOS) to prevent failure.

One such rule is: (Taylor's equation)

$$FOS = \frac{6C}{\gamma H}$$

where:

C = cohesion of soft foundation foil

γ = unit weight of embankment soil

H = Height of slope

The FOS computed using the above equation should not be used for final design. This simple equation can be used to preliminarily check both slope and foundation (base) stability. If the factor of safety is less than 2.5, a more sophisticated stability analysis is required.

Preliminary FOS = **7.142857** > 2.5

Ok for preliminary design. Must be reevaluated for final design when plans are available

Action Item: Perform Settlement Estimate under bearing pressure computed at a Service I limit State.

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Retaining Wall Analysis - Settlement Check

Per AASHTO with 2017 Interim Editions

Project: Intersection Improvement at 17th Street with North Dunn Street
Soil Boring : RW-2
Scope : Wall Settlement Determination
Analyzed by : EAW

All parameters calculated based upon boring specific unit weight and moistures content tests. Specific gravity testing and Atterberg Limit testing was performed on parent soil type.

Definitions:

w moisture content
g_d dry unit weight of soil
LL Liquid Limit
Cc Compression Index*
** Calculated by correlation, INDOT GSS Manual Table 6.1*
Cc = 0.156eo+0.0107
All Clays

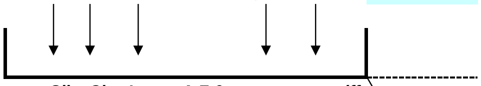
Cr Recompression Index

e_o initial void ratio**
***Calculated using void ratio relationship*

$$e_o = \frac{G_s \gamma_w}{\gamma_d} - 1$$

h Height of layer
G_s Specific Gravity
γ_s unit weight of soil

q_o (bearing pressure under Service I limit state) = 2780 psf



Ground Surface Elev.: 812
Btm. Leveling pad Elev 807.5 ft
Btm Foundation zone. 804.5

Silty Clay Loam, A-7-6 ***stiff***

w	32.0%			
γ_s	120.0	pcf		
γ_d	90.944	pcf		
LL	46			
Cc	0.140	*calculated value*		
e_o	0.83	*calculated value*		
h	3.0	feet	36	inches
Gs	2.67			

Depth: 10.5
Elev.: 801.5 ft

Rock

Step 1: Calculate all stresses

Water Depth	10.5	
Soil Layer		1
Depth	10.5	10.5
Unit Weight	120.0	120.0
Pore Water Pressure	0	0
Pore Water Pressure at Midpoint	0	0
Total Stress at Midpoint	630	1260
Total Stress for Layer	1260	1260
Effective Vertical Stress at Midpoint	630	1260
Effective Vertical Stress for Layer	1260	1260

Water Table: 10.5 ft

GW Elev.: 797.0 ft

Step 2: Calculate the increase of vertical pressure for compressible layers (***Δp)***

Footing Size B= 8 feet
L= 135 feet
1080 ft^2
Load on footing = 2779.6 psf
3002000.0 pounds
Use a 1(H):2(V) pressure distribution

Layer 1 **Δp_1** 2542.26 psf at center of layer

Step 3: Calculate Settlement of the first compressible layer

p_{o1} 1260 psf is present at midpoint of **Silty Clay Loam, A-7-6**

$$S_C = \frac{C_c H}{1+e_o} * \log\left(\frac{p_o + \Delta p}{p_0}\right)$$

S_1 1.3 inches
0.03 m

within the **Silty Clay Loam, A-7-6**

Step 4: Determine total estimated settlement **(*S_T*)** of system

S_T 1.3 inches***
0.03 m

****Per INDOT GSS Manual 6.1*

For very soft to soft clays (Qu between 0.25 to 0.50 tsf), the settlements computed by this method are likely to be reasonably accurate. For medium and stiff clays (Qu between 0.5 and 2.0 tsf), the actual settlements are likely to range between one-fourth and one-tenth of the computed values.

*Influence values determined using chart (Table 8.5) provided in Holtz & Kovaks (1981)

For medium stiff tostiff clays, the actual settlement is expected to range from one-fourth to one-tenth of the computed value. No additional Analysis needed.

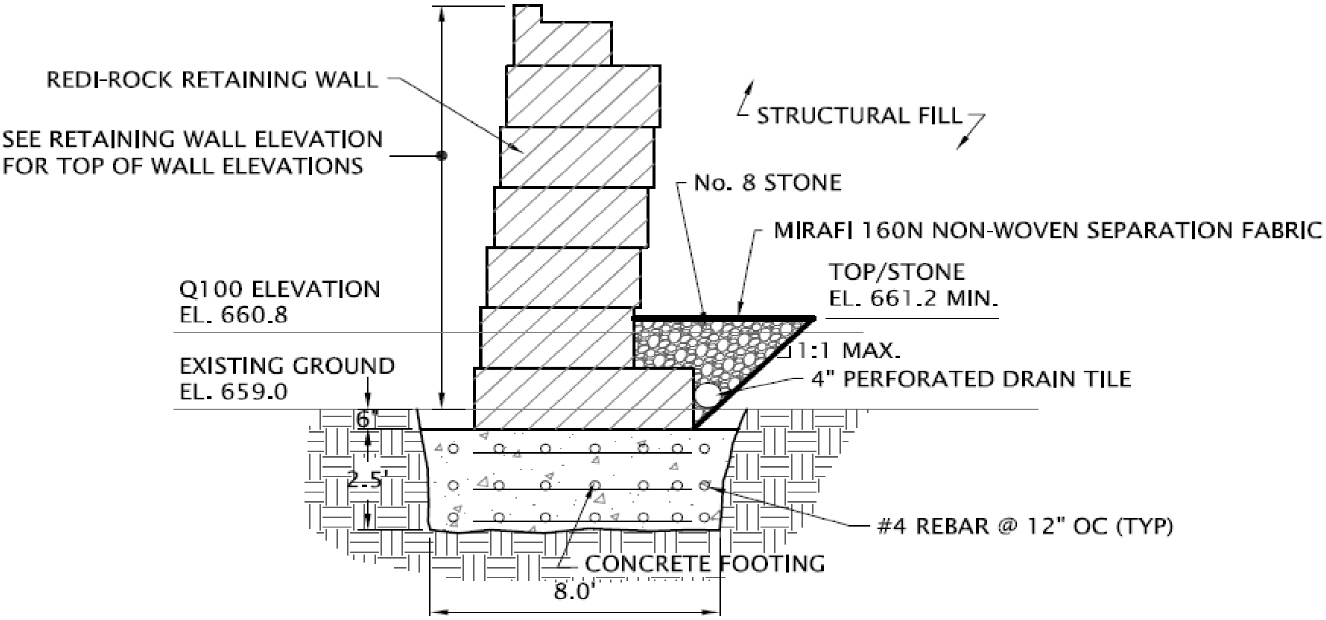
Retaining Wall Analysis - Prefabricated Modular Walls

Per AASHTO with 2017 Interim Editions

Project: Intersection Improvement at 17th Street with North Dunn Street
Location: Bloomington, IN
DES No.: N/A Job # 170GC00756
Soil Boring : RW-2
Scope : Retaining Wall External Analysis
Analyzed by : EAW

Design Recommendations:

Required Minimum Base Width to Wall Height Ratio= **0.7** or a minimum base width of 8 ft



Total Wall Height, H =	9	ft	*Minimum Base Width, B =*	8	ft
Foundation Height =	0	ft	Block Set Back =	1.62	in
All Block Heights =	1.5	ft	Bottom Block Set Back =	1.62	ft

Block Quantity:

Type 1	1	@	27.8	in
Type 2	4	@	40.5	in
Type 3	1	@	60.0	in

Nominal Bearing Resistance (q_n) = *5559* *psf*

φ_b resistance factor (Table 10.5.5.2.2-1) *0.50*

Recommended Factored Unit Bearing Resistance (q_R) = ***2800*** ***psf***